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Prepared for

**UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION 5**

77 West Jackson Boulevard, SR-6J
Chicago, Illinois 60604

***Remedial Investigation/Feasibility Study
Planning Documents - Revision 1***

***Matthiessen and Hegeler Zinc Company Site
LaSalle, Illinois***

***Work Plan (Operable Unit 1)
Field Sampling Plan
Health & Safety Plan
Quality Assurance Project Plan***

On behalf of



**CARUS CORPORATION AND
CARUS CHEMICAL COMPANY**

1500 Eighth Street
P.O. Box 1500
LaSalle, Illinois 61301-3500

Prepared by

Geosyntec 
consultants

engineers | scientists | innovators

2258 Riverside Avenue
Jacksonville, Florida 32204

14 May 2007

RIFS WORK PLAN



Prepared for

**Carus Corporation and
Carus Chemical Company**

1500 Eighth Street

P.O. Box 1500

LaSalle, Illinois 61301-3500

**WORK PLAN FOR
REMEDIAL INVESTIGATION/FEASIBILITY
STUDY (RI/FS), OPERABLE UNIT 1
REVISION 1**

**MATTHIESSEN AND HEGELER ZINC COMPANY
SITE**

LASALLE, ILLINOIS

Prepared by

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2258 Riverside Avenue
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Project Number FR1093

May 2007

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1 Terms of Reference.....	1
1.2 Document Overview	2
2. SITE SETTING	4
2.1 Site Location.....	4
2.2 Site Operations History.....	4
2.3 Site Description	5
2.4 Physiography and Climatology.....	6
2.5 Demographics	7
2.6 Hydrology, Geology, and Hydrogeology	7
2.6.1 Surface Hydrology.....	8
2.6.1.1 Regional Surface Hydrology.....	8
2.6.1.2 OU1 Surface Hydrology.....	8
2.6.1.3 Physical Characteristics of Little Vermilion River	8
2.6.2 Geology.....	9
2.6.2.1 Regional Geology.....	9
2.6.2.2 Geologic History.....	11
2.6.2.3 Site Geology and Stratigraphy	12
2.6.3 Hydrogeology.....	16
2.6.3.1 Regional Hydrogeology	16
2.6.3.2 OU1 Hydrostratigraphy.....	16
2.6.4 OU1 Flow Systems	18
2.6.4.1 Overview.....	18
2.6.4.2 Description of the Main Plant Area Flow System	18
2.6.4.3 Description of the Slag Pile Flow System	19

TABLE OF CONTENTS (continued)

2.6.4.4	Direction and Rate of Flow	19
3.	CURRENT UNDERSTANDING OF THE NATURE AND EXTENT OF CONTAMINATION.....	22
3.1	Introduction.....	22
3.2	Chronology and Rationale of Historical Investigations.....	22
3.3	Summary of Investigative Findings	25
4.	CONCEPTUAL SITE MODEL	28
4.1	Introduction.....	28
4.2	Physical Conceptual Model	29
4.3	Submedia Analysis and Preliminary Metals Priority Ranking	33
4.4	Discussion of Metals Geochemistry	36
4.4.1	Characteristics of Individual Metals	36
4.4.1.1	Antimony	37
4.4.1.2	Arsenic	37
4.4.1.3	Beryllium	37
4.4.1.4	Cadmium.....	37
4.4.1.5	Chromium	38
4.4.1.6	Copper.....	38
4.4.1.7	Iron.....	39
4.4.1.8	Lead.....	39
4.4.1.9	Manganese	40
4.4.1.10	Mercury.....	40
4.4.1.11	Nickel	41
4.4.1.12	Selenium	41
4.4.1.13	Silver	41
4.4.1.14	Thallium.....	42
4.4.1.15	Zinc	42
4.4.2	Summary of Geochemical Controls for Priority Metals	42

TABLE OF CONTENTS (continued)

4.5	Vertical Distribution of Metals in Site Media	44
4.6	Occurrence of Organic Constituents of Concern and Cyanide	44
4.7	Potential for Asbestos Presence.....	46
4.8	Conceptual Model Summary	46
5.	RI/FS OVERALL GOALS AND REQUIREMENTS.....	49
5.1	Introduction to Objectives	49
5.2	Necessary Components of the RI/FS	50
5.3	Evaluation of Potential ARARs.....	51
6.	CURRENT DATA NEEDS.....	53
6.1	Introduction.....	53
6.2	Physical Characterization Needs.....	53
6.3	Nature and Extent of Contamination	53
6.4	Fate, Transport, and Risk Mechanisms.....	55
6.4.1	Rationale.....	55
6.4.2	Description of Specialty Analyses	56
6.4.2.1	Acid Volatile Sulfide/Simultaneously Extracted Metals	56
6.4.2.2	Sequential Extraction Procedure.....	57
6.4.2.3	Other Specialty Methods.....	59
6.4.2.4	Other Risk Assessment-Related Data	60
6.5	Remedy Evaluation Data	60
7.	REMEDIAL INVESTIGATION SCOPE OF WORK	61
7.1	Introduction.....	61
7.2	Solid Matrix Characterization Program.....	61
7.3	Surface-Water and Sediment Characterization Program	64
7.3.1	River Characterization Program	64
7.3.2	Upland Characterization Program	65

TABLE OF CONTENTS (continued)

7.4	Groundwater Characterization Program	66
7.4.1	Introduction.....	66
7.4.2	Well Reconnaissance and Rehabilitation.....	67
7.4.3	Well Network Expansion.....	68
7.4.4	Monitoring Well Sampling.....	68
7.4.5	Potentiometric Gauging.....	68
7.4.6	Hydraulic Characterization	69
7.5	Ecological Habitat Characterization Program	69
7.6	Human Health Risk Assessment.....	70
7.6.1	Introduction.....	70
7.6.2	Definition of Assessment Area.....	71
7.6.3	Evaluation of Data	71
7.6.4	Identification of COPCs.....	72
7.6.4.1	Overview	72
7.6.4.2	Methodology	72
7.6.5	Exposure Assessment	73
7.6.6	Toxicity Assessment.....	76
7.6.7	Risk Characterization.....	76
7.6.8	Uncertainty Analysis.....	77
7.6.9	Assessment of Asbestos Data for Ambient Air	77
7.7	Ecological Risk Assessment.....	78
7.7.1	Overview.....	78
7.7.2	Purpose and Objectives of the SLERA	80
7.7.3	Screening-Level Problem Formulation.....	81
7.7.3.1	Site Characterization and Environmental Setting.....	82
7.7.3.2	Receptors of Interest	82
7.7.3.3	Chemicals of Potential Concern.....	83

TABLE OF CONTENTS (continued)

7.7.3.4	Assessment and Measurement Endpoints.....	84
7.7.3.5	Ecological Conceptual Site Model.....	86
7.7.4	Analysis	86
7.7.4.1	Exposure Characterization	87
7.7.4.2	Effects Characterization.....	87
7.7.5	Screening-Level Risk Characterization	88
7.7.6	Risk Management and Additional Evaluation	89
7.7.7	Baseline Ecological Risk Assessment	89
7.8	Surface-Water Basin Analyses	92
7.9	Remedial Investigation Report	93
8.	FEASIBILITY STUDY SCOPE OF WORK	94
8.1	Overview.....	94
8.2	Treatability Studies	95
8.3	Feasibility Study Report	96
9.	PROJECT MANAGEMENT AND CONTROL	98
9.1	Data Management Plan	98
9.2	Schedule.....	99
10.	REFERENCES CITED.....	100

LIST OF TABLES

Table 1	Summary of Hydraulic Conductivity Data
Table 2a	Solid Matrix Screening by Submedium and Priority Metals Determination
Table 2b	Groundwater Screening by Submedium and Priority Metals Determination

TABLE OF CONTENTS (continued)

LIST OF TABLES (continued)

Table 2c	Sediment Screening and Priority Metals Determination
Table 2d	Surface-Water Screening and Priority Metals Determination
Table 3	Media Screening Summary and Priority Metals Determination
Table 4	Comparison of Groundwater Summary Statistics and P-1 Results
Table 5	Potential Federal and State ARARs and TBCs
Table 6	Sample Locations, Depths, and Analyses for Solid, River, and Groundwater Sampling
Table 7	Database Documentation

LIST OF FIGURES

Figure 1	Approximate Boundary of Matthiessen and Hegeler Zinc Company Superfund Site
Figure 2	Overview of Historical Process Areas
Figure 3	East-West Cross-Section
Figure 4	Potentiometric Surface, Carus Main Plant, Shallow Aquifer System on 17 November 1993
Figure 5a	Historical Sampling Locations (Southern)
Figure 5b	Historical Sampling Locations (Northern)
Figure 6	Conceptual Site Model of Upland Process Areas, Slag Pile, and River
Figure 7	Unincorporated Areas Within 2,500 Ft of Buffer of OU1
Figure 8a	Antimony in Multimedia
Figure 8b	Arsenic in Multimedia
Figure 8c	Beryllium in Multimedia
Figure 8d	Cadmium in Multimedia
Figure 8e	Chromium in Multimedia
Figure 8f	Copper in Multimedia
Figure 8g	Iron in Multimedia
Figure 8h	Lead in Multimedia
Figure 8i	Manganese in Multimedia
Figure 8j	Mercury in Multimedia

TABLE OF CONTENTS (continued)

LIST OF FIGURES (continued)

Figure 8k	Nickel in Multimedia
Figure 8l	Selenium in Multimedia
Figure 8m	Silver in Multimedia
Figure 8n	Thallium in Multimedia
Figure 8o	Zinc in Multimedia
Figure 9	Generalized Effect of pH and Oxidation-Reduction Potential on Priority Metals Mobility
Figure 10	pH and ORP in Groundwater, November 1994
Figure 11	Three-Dimensional Distribution of Selected Metals in Site Media
Figure 12a	Existing Distribution of Soil Analytical Methods and Exceedances for Organics and Cyanide
Figure 12b	Existing Distribution of Groundwater Analytical Methods and Exceedances for Organics and Cyanide
Figure 12c	Existing Distribution of Sediment Analytical Methods and Exceedances for Organics and Cyanide
Figure 12d	Existing Distribution of Surface-Water Sampling Locations and Exceedances for Cyanide
Figure 13a	Proposed Solid Matrix Sampling Locations
Figure 13b	Proposed River Sampling Locations
Figure 13c	Proposed OU1 Monitoring Well Network
Figure 14	Proposed Schedule of Completion Remedial Investigation/Feasibility Study

LIST OF APPENDICES

Appendix A	Field Sampling Plan
Appendix B	Quality Assurance Project Plan
Appendix C	Health and Safety Plan
Appendix D	Standard Operating Procedures
Appendix E	Electronic Data Deliverables on CD

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS

ADD	Average Daily Dose
AOI	Area of Interest
ARAR	Applicable or Relevant and Appropriate Requirement
ASAO	Administrative Settlement Agreement and Order on Consent
AVS/SEM	Acid Volatile Sulfide/Simultaneously Extracted Metals
AWQC	Ambient Water Quality Criteria
BERA	Baseline Ecological Risk Assessment
BLS	Below Land Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
COPC	Chemical of Potential Concern
CSM	Conceptual Site Model
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DQO	Data Quality Objective
Eco-SSL	Ecological Soil Screening Levels
ECSM	Ecological Conceptual Site Model
EDD	Electronic Data Deliverable
EI	Environmental Indicator
ERA	Ecological Risk Assessment
ERL	Effects Range Low
ET	Ecotoxicological Threshold
FS	Feasibility Study
FSP	Field Sampling Plan
Geosyntec	Geosyntec Consultants
GIS	Geographic Information System
GPS	Global Positioning System

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS (continued)

HASP	Health and Safety Plan
HEAST	Health Effect Summary Table
HHCSM	Human Health Conceptual Site Model
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
HRS	Hazard Ranking System
ICRR	Illinois Central Railroad
IDPH	Illinois Department of Public Health
IEPA	Illinois Environmental Protection Agency
IRIS	Integrated Risk Information System
LADD	Lifetime Average Daily Dose
M&H	Matthiessen and Hegeler
MCL	Maximum Contaminant Level
NCP	National Contingency Plan
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No-Observed-Adverse-Effect-Levels
NPDES	National Pollutant Discharge Elimination System
NPL	National Priority List
ORNL	Oak Ridge National Laboratory
ORP	Oxidation-Reduction Potential
OSHA	Occupational Safety and Health Administration
OU1	Operable Unit 1
OU2	Operable Unit 2
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCM	Phase Contrast Microscopy
PRG	Preliminary Remedial Goal
PPRTV	Provisional Peer Reviewed Toxicity Value

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS (continued)

PSI	Preliminary Site Investigation
QAPP	Quality Assurance Project Plan
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RDA	Recommended Daily Allowances
RfD	Reference Dose
RI	Remedial Investigation
ROD	Record of Decision
SADI	Safe and Adequate Daily Intake
SARA	Superfund Amendments and Reauthorization Act
SEP	Sequential Extraction Procedure
SF	Slope Factor
SLERA	Screening-Level Ecological Risk Assessment
SMDP	Scientific/Management Decision Point
SOP	Standard Operating Procedure
SPLP	Synthetic Precipitation Leaching Procedure
SQB	Sediment Quality Benchmark
SQC	Sediment Quality Criteria
SSI	Screening Site Inspection
SVE	Soil Vapor Extraction
SVOC	Semi-Volatile Organic Compound
TACO	Tiered Approach to Corrective Action Objectives
TAL	Target Analyte List
TBC	To Be Considered
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TLR	Technical Letter Report
TOC	Total Organic Carbon
UCL	Upper Confidence Limit
USDA	United States Department of Agriculture

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS (continued)

USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VOC	Volatile Organic Compound
XRD	X-Ray Diffraction

1. INTRODUCTION

1.1 Terms of Reference

This Work Plan has been prepared by Geosyntec Consultants (Geosyntec) as part of the Operable Unit 1 (OU1) Remedial Investigation/Feasibility Study (RI/FS) for the Matthiessen and Hegeler (M&H) Zinc Company Site (Site) located in LaSalle, Illinois. The RI/FS is required by an Administrative Settlement Agreement and Order on Consent (ASAOC) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No.V-W-06-C-856, dated 6 October 2006, between United States Environmental Protection Agency (USEPA) Region V, Carus Corporation, and Carus Chemical Company (Carus), pursuant to the CERCLA. During the course of the RI/FS, environmental samples will be collected to: (i) characterize the nature and extent of any contamination stemming from past site practices, as well as the risks to human health and the environment stemming therefrom; and (ii) develop and evaluate remedial alternatives for the Site. This Work Plan is written for OU1 to: (i) provide background information; (ii) develop the preliminary Conceptual Site Model (CSM) and overall management goals; and (iii) present a scope of work for further OU1 assessment, risk assessment, and remedial alternatives evaluation.

This Work Plan is one of several RI/FS Planning Documents submitted concurrently in fulfillment of Task 1.3 of Appendix A (Statement of Work) of the ASAOC. Other concurrently submitted documents include the following:

- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site (Appendix A to this document);
- Quality Assurance Project Plan (QAPP), written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization (Appendix B to this document); and

- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards (Appendix C to this document).

Standard Operating Procedures (SOPs), which provide the protocols for field operations, are also submitted concurrently (Appendix D), as well as historical data on disk (Appendix E). The RI/FS Planning Documents draw upon a Technical Letter Report (TLR) (Geosyntec, 2006) previously submitted to USEPA Region 5 in fulfillment of Task 1.1 of Appendix A of the ASAO. Sections 2 and 3 of this Work Plan respectively summarize the descriptions of the site setting and nature and extent of contamination that are presented in the TLR. The reviewer is referred to the TLR for a more detailed discussion of these topics.

1.2 Document Overview

This Work Plan has been prepared according to the USEPA guidance document “Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA” (USEPA, 1998).

The remainder of this Work Plan is organized as follows:

- Section 2 provides the OU1 setting, including the site history relative to OU1 and a description of the local and regional physical, biological, and demographic features of the Site vicinity;
- Section 3 discusses the current understanding of the nature and extent of contamination, drawing upon past characterization work as presented in the TLR;
- Section 4 develops the CSM;
- Section 5 outlines the RI/FS overall goals and requirements;
- Section 6 summarizes current data needs;

- Section 7 discusses the RI scope of work;
- Section 8 presents the FS scope of work;
- Section 9 discusses project management and control; and
- Section 10 of this document provides references cited.

2. SITE SETTING

2.1 Site Location

OU1 is a portion of the broader M&H Zinc Company Site, located on the east side of LaSalle, Illinois. Figure 1 presents an overview of the Site, which encompasses approximately 183 acres of defined property plus any off-property areas, such as the Little Vermilion River, which may have been affected by the Site's manufacturing history. The Site is divided into two operable units: (i) OU1, comprising the Carus facility in the southern portion of the site, the slag pile created from M&H operations, and the Little Vermilion River; and (ii) Operable Unit 2 (OU2), comprising the former M&H Zinc Company in the northern portion of the site, as well as any impacts to residential or other areas in the City of LaSalle. The ASAOC requires Carus' participation in a site-wide RI/FS, which, for Carus, specifically entails: (i) performance of OU1-related activities; and (ii) combination of investigative findings from OU1 with those from OU2 provided by USEPA's contractor into site-wide reports, as needed.

2.2 Site Operations History

The TLR presents a detailed, chronological review of site history for OU1 and OU2, including an aerial photograph review. This section presents a summary of the operational history of OU1 and OU2. For a more detailed discussion, the reviewer is referred to the TLR. This summary begins with a discussion of OU2, the former M&H Zinc Company Site, because its process origins predate and are directly relevant to OU1.

OU2 property, located at 900 Sterling Street north of the Carus manufacturing facility, began primarily as a zinc processing facility in the mid-1800's under the name of Matthiessen and Hegeler. Zinc ore was imported to the M&H property where it was refined, recovered, and rolled for industrial use. In the late-1800's, Matthiessen and Hegeler exploited a new technology whereby the sulfur dioxide emissions from the zinc refining process could be converted to sulfuric acid; this became another plant process. By-products, including sinter, slag, and other off-specification materials, were placed south and east of the M&H plant in the area that is now between the M&H and Carus

plants and the Little Vermilion River. Portions of the slag and sinter were placed on property now owned by Carus. Based on comparisons of aerial photographs, by 1939, most of the slag had been placed in its current location. In the late 1970's, M&H Zinc Company reportedly filed for bankruptcy, and operation of the rolling mill was taken over by Zinco. In 1991, Zinco merged with LaSalle Rolling Mills, which was the surviving corporation. LaSalle Rolling Mills continued operations until the late 1990's and performed smelting, rolling, casting, stamping, and plating of zinc and aluminum sheet and wire products. Beyond some warehousing, there are no known current operations on the former M&H property comprising OU2.

Based on the plat survey, in 1876, a large portion of the property now owned by Carus (i.e., OU1) was likely used for agricultural purposes. The manufacturing and business operations of Carus and M&H have always been separate. Carus began operations in 1915 manufacturing potassium permanganate products used for water purification and wastewater treatment. Today, approximately 15,000 tons of potassium permanganate are produced annually at the Carus facility. Additionally, Carus produces sodium permanganate and a specialty line of products. Sodium permanganate is used by the electronics industry for descumming and descaling. Other products are used for denim highlighting, chemical synthesis and purification, wire descaling, and acid mine leachate treatment. Air filter media are produced for air purification use in residential, commercial, and industrial buildings. The reviewer is referred to the TLR for a more detailed discussion of current Carus operations.

2.3 Site Description

OU1 is comprised of three areas: (i) Carus' manufacturing facility; (ii) a slag pile related to the former M&H smelter operations; and (iii) the Little Vermilion River. The Carus manufacturing facility is located at 1500 Eighth Street, in the northwest quarter of Section 14 and in the northeast quarter of Section 15 in Township 33 North, Range 1 East of the Third Principal Meridian in LaSalle County, Illinois. The slag pile is located in the northwest quarter of Section 14 in the township referenced above and is bordered to the east by the Little Vermilion River. The river generally runs from north to south toward its confluence with the Illinois River approximately one mile south of the Site; it also serves as the eastern boundary of OU1 and OU2. A location map is provided as

Figure 2. Note that the northern boundary of the slag pile serves as part of the boundary between OU1 and OU2; this boundary is dashed on associated figures because the boundary is estimated at present. Likewise, the spatial extent of site-related impacts in the Little Vermilion River will be better understood during and after RI characterization; hence, dashed boundary lines immediately to the north and south of the Site indicate possible study boundaries. Although proposed physical characterization of the slag will extend to the Illinois River during the first phase of the RI, sediment and surface-water samples collected for laboratory analyses will initially be focused within the dashed boundary limits to the north and south of the Site. The main plant area of Carus contains numerous buildings associated with the manufacture of potassium permanganate and other specialty chemicals. Property to the east of the main plant area includes, from west to east: (i) the eastern embankment of the manufacturing facility; (ii) a segment of the former Illinois Central Railroad (ICRR) embankment; and (iii) the slag pile associated with the M&H Zinc Company Site. A holding pond and an emergency bypass pond associated with Carus' operations and its National Pollutant Discharge Elimination System (NPDES) permit (Number IL0002623) are located on or near the slag pile. OU1 is bounded by OU2 of the M&H Zinc Company Site to the north; a limestone quarry, a cemetery, and farmland to the east; and private residences to the south and west.

2.4 Physiography and Climatology

The Carus manufacturing facility is located within LaSalle County, which consists of a flat upland area with an average elevation of 650 to 750 ft (1927 North American Datum). The facility lies at an elevation of approximately 580 ft, except near the eastern boundary of the site, where the elevation decreases to approximately 460 ft at the boundary of the Little Vermilion River. The Little Vermilion River flows from north to south for approximately one mile from the facility where it discharges into the Illinois River. The Illinois River Valley divides LaSalle County into approximately two equal sections. The Illinois River Valley is approximately one mile wide at the County of LaSalle, with relatively steep bluffs approaching 150 ft high.

The temperature in the City of LaSalle varies between approximately 18°F in January to 86°F in July. Mean annual rainfall is approximately 34 inches. The prevailing wind is from the south with an average velocity of 11 mph.

2.5 Demographics

According to 2000 census data, the City of LaSalle has a population of 9,796. The population density in neighborhoods immediately west of the Site ranges from 64 persons/mi² at the north end of the Site to 1,700 persons/mi² at the south end. The age distribution of LaSalle residents, compared to national averages, is as follows:

- median age: 38.1 years (35.3 nationally);
- population under five years of age: 6.6% (6.8% nationally);
- population 18 years of age or older: 76.6% (74.3% nationally); and
- population 65 years of age or older: 18.7% (12.4% nationally).

While 2005 estimates are not available for the City of LaSalle, estimates for the County of LaSalle indicate a decline in population from 111,509 in 2000 to 109,658 in 2005. These age statistics and population trends suggest that the population is stable to declining and that significant changes in land use in the near future are not likely based on current trends.

2.6 Hydrology, Geology, and Hydrogeology

The information presented in this section is based on boring logs and field notes from previous field investigations, as well as published literature. A detailed description of the regional and OU1 hydrology, geology, and hydrogeology is presented in this section. Cross-sections were developed based on the results of prior investigations; they illustrate Geosyntec's understanding of the geologic profile of areas within OU1. The reviewer is referred to the TLR for a complete set of cross-sections; however, a single east-west cross-section is provided in this Work Plan as Figure 3. This cross-section is

presented because it succinctly presents the relationship between the slag pile and the upland areas of OU1.

2.6.1 Surface Hydrology

2.6.1.1 Regional Surface Hydrology

LaSalle County lies within the Illinois River Drainage Basin. The Illinois River flows across the central portion of LaSalle County in a westerly direction. Overall, LaSalle County is moderately well-drained, although marshes occur near the headwaters of some upland creeks. Important tributaries of the Illinois River include the Fox River, the Vermilion River, and the Little Vermilion River, the latter of which flows from north to south along the eastern property boundary of the site.

2.6.1.2 OU1 Surface Hydrology

The most important feature influencing surface-water flow at and near the Site is the Little Vermilion River. The majority of the surface-water runoff across OU1 flows toward the holding pond. The holding pond discharges to the Little Vermilion River through a NPDES permitted discharge pipe. The easternmost edge of the slag deposits occur within the 100-year flood plain of the Little Vermilion River as designated by the United States Geological Survey (USGS). In general, surface-water runoff across OU2 is directed toward the Little Vermilion River.

2.6.1.3 Physical Characteristics of Little Vermilion River

Observations concerning the dimensions, flow rates, and substrate nature of the Little Vermilion River stem from site reconnaissance performed during the preparation of this Work Plan as well as data collection and calculations performed by Geosyntec (1996.)

On 7 October 1994, Geosyntec profiled the depth and velocity of the river in four transects adjacent to the slag pile. The associated flowrate ranged from 6 to 14 ft³/s. River width varied considerably, from 15 to 55 ft, depending upon the degree of constriction due to the slag pile and the steep valley wall on the eastern bank. Maximum river depth also varied from 1.4 to 2.9 ft, and the peak velocity in a given

transect varied from 0.51 to 1.27 ft/s. It should be noted that shortly after this measurement event, heavy rains raised the river level by two feet; as a result, it was unsafe to perform additional velocity profiling.

The riverbed substrate is variable and requires understanding in the context of the unique geologic configuration of the river. As discussed in greater detail in Section 2.6.2, Holocene alluvial deposits brought about by the river were generally buried by the slag pile, which displaced the waterway to the east to zones of relatively clean bedrock or cobbles. Limited reconnaissance of the river performed in May 2007 indicated that immediately north of the slag pile, alluvial sand bars are present. However, as the river runs alongside the slag pile, its course is constricted, which causes the gradient to steepen and velocities to increase, which has apparently scoured the majority of any remaining alluvium from the riverbed. The riverbed contains occasional large (1-2 ft in length) chunks of slag (slag is discussed in greater detail in Section 2.6.2.) While the river substrate is generally coarse rock or bedrock, limited zones of alluvial sediment are deposited in the littoral zone close to the riverbank, most commonly in the lee of large rocks or chunks of slag. The extent to which small slag pieces are present in the sediment is not well understood at present. Also, a limited stretch of the river (on the order of several hundred feet in length) appears to have more significant alluvial overbank deposits on the western boundary.

In general, the river valley walls adjacent to the site are relatively steep; hence, with the exception of limited sandbars within or immediately adjacent to the river, wetlands have not been observed in the river valley.

2.6.2 Geology

2.6.2.1 Regional Geology

The regional geology of north-central Illinois consists of unconsolidated Pleistocene glacial deposits overlying Paleozoic sedimentary deposits. For the purposes of this investigation, the Paleozoic strata can be divided into lower Paleozoic deposits and upper Paleozoic deposits. The lower Paleozoic deposits consist primarily of sandstone, dolomite, and shale, and are on the order of 4,800 ft thick. The upper Paleozoic

deposits, which are entirely of Pennsylvanian age, consist primarily of shale, limestone, sandstone, and coal, and are on the order of 400 ft thick. The distinction between lower and upper Paleozoic deposits is significant with respect to the LaSalle Anticline, which is the most important geological structure in the region.

The LaSalle Anticline is a sharp, southwestward-dipping flexure in the lower Paleozoic sedimentary strata. The flexure was formed after deposition of the lower Paleozoic strata but before deposition of the upper Paleozoic strata. The axis of flexure on the northwest to southeast trending anticline is located approximately one mile to the northeast of the site. The effect of this flexure is that lower Paleozoic strata that exist at depths of 1,500 ft at an approximate distance of 1.5 mile to the southwest of the site are exposed at or near the ground-surface about one mile to the northeast of the site. However, this sharp flexure does not occur within the upper Paleozoic (Pennsylvanian) strata. The upper Paleozoic deposits merely overlap and thin against the flexure.

During the Mesozoic and early Cenozoic periods in Illinois, emergence of the Paleozoic formations resulted in widespread erosion and production of a low-relief topography. During the Pleistocene Epoch, glaciers advanced over the region, scouring out softer rocks and soils. As the ice melted, large volumes of rock and soil debris were left behind in the form of glacial drift. Glacial drift deposits range up to 600 ft in thickness in the region.

Glacial-drift thicknesses near the site were estimated from formation descriptions provided in well construction reports submitted by well drillers to the Illinois Department of Public Health (IDPH). Within a 5-mile radius of the site, drift thicknesses range from less than 10 ft to approximately 100 ft. The average thickness of glacial deposits is approximately 40 ft within an area bounded to the south by the Illinois River and the east by the Little Vermilion River. South of the Illinois River and west of the Vermilion River, glacial deposits average approximately 60-ft thick. Northeast of the site, across the Little Vermilion River, glacial deposits appear to be 10-ft thick or less. Pennsylvanian age and older formations outcrop to the east of the Little Vermilion River, as the crest of the LaSalle Anticline is approached.

2.6.2.2 Geologic History

The bedrock of OU1 consists of shale and limestone with small amounts of coal and sandstone. These rocks were deposited about 300 million years ago during the Pennsylvanian Period in shallow marine and swamp environments. Following deposition, these deposits were buried, compacted, and cemented into moderately to well-consolidated sedimentary rock.

Glaciers scoured valleys into the Pennsylvanian deposits during the Pleistocene Epoch, about 20,000 years ago. This scouring created an irregular surface of fresh bedrock beneath the ice. When the ice melted, large volumes of sediment ranging in size from boulders to silt were left behind as deposits of till. In some places, silty clay was deposited by wind or standing water.

Following, and also possibly during the Pleistocene Epoch, erosion scoured out the Little Vermilion Gorge and appears to have removed nearly all of the glacial deposits from OU1, except for a small erosional remnant in the northeastern corner of the Carus main plant area. Where Pennsylvanian shales were exposed, up to 8 ft of residual soils have developed. In the central part of the Carus main plant area, an erosional gully formed. Also, during this time, stream and floodplain sediments were deposited in the Little Vermilion Valley.

In the mid 1800's, zinc smelting began just to the north of OU1 and large amounts of slag and some waste sinter were produced. Waste slag was taken from the retorts and transported to OU1 by a narrow-gauge railroad. From the mid-1800's to the early 1900's, a long ridge of slag was deposited along the eastern side of the current Carus main plant area. This ridge of slag has the appearance of a berm constructed across the mouth of the gully.

General infilling of the gully likely began following construction of the slag ridge. In the northeastern part of the impounded gully, which was close to the narrow gauge railroad, much of the fill material consisted of waste sinter from smelting operations. In most of the gully, however, fill material consisted of fresh to weathered Pennsylvanian green shale. This shale appears to have been scraped from a small knoll that probably

existed near the location of the gully. In the early stages of infilling, a shallow pond appears to have formed in the gully, causing deposition of the soft, alluvial soils observed in Borings C-3 and G-05.

According to a historic site map, by 1928, infilling of the gully had been completed and the area was traversed by the tracks of the LaSalle and Bureau County Railroad. The 1928 map also shows the earliest Carus buildings. The railroad tracks were removed in the 1970's. Around 1980, the emergency storage area was constructed on the Carus main plant area utilizing an engineered, compacted clay liner, designed to contain liquids in an emergency situation.

2.6.2.3 Site Geology and Stratigraphy

Overview: The rocks and soils beneath OU1 were formed as either natural or man-made deposits of sediment and fill material. Each type of deposit has chemical and hydrogeologic properties which are unique and individually significant to the flow and chemical composition of the shallow groundwater beneath OU1. For this report, these deposits can be divided into four general groups on the basis of age and origin:

- the Pennsylvanian System, which includes the bedrock and residual soils formed upon it;
- the Pleistocene Series, which includes the glacial deposits in the northeastern corner of the main plant area;
- Holocene alluvium, which is confined to the bottom of the Little Vermilion Valley; and
- modern fill, which includes all materials which have been deposited or reworked by human action since the onset of industrial operations.

The remainder of this section consists of a systematic description of each of these four groups of materials, including: (i) overall makeup and distribution; (ii) internal composition; and (iii) a general description of hydrogeologic properties, if applicable.

Pennsylvanian System: The Pennsylvanian System constitutes the bedrock and underlies the entire area around OU1. Within the area of investigation, the Pennsylvanian System consists of horizontal or nearly horizontal layers of shale and limestone with a few thin beds of coal and sandstone. In many areas, a mantle of residual soil has developed within the upper few feet of the Pennsylvanian deposits. The full Pennsylvanian section at OU1, down to the level of the Little Vermilion River, is shown on the east-west cross-section (Figure 3). On the cross-section, the Pennsylvanian System was divided, from the top down, into the following four units: (i) green shale, which includes some coal and gray claystone; (ii) red shale; (iii) limestone; and (iv) gray shale with thin beds of limestone.

The green shale unit actually consists of several layers of green, calcareous shale, a layer of green calcareous siltstone, a thin bed of coal, a layer of gray claystone, a layer of bituminous clay and shale, and at least one thin bed of marlstone. Additionally, within several feet of the natural ground surface, a mantle of residual soil has developed in the top of the green shale unit.

In the layers of green calcareous shale and siltstone, groundwater appears to flow slowly through small, widely spaced fractures. Where weathering has reduced the amount of calcareous cement, some intergranular flow may also take place. The intergranular hydraulic conductivity of the weathered green shale at Monitoring Well G-02 was measured to be 9.9×10^{-7} cm/s on the basis of laboratory hydraulic conductivity testing.

Although it is very thin, the coal bed is highly fractured and therefore has high hydraulic conductivity, probably giving it a transmissivity comparable to the entire calcareous green shale section. During the drilling of Monitoring Well G-03, free water was not encountered in the split-spoon samples, except when the coal bed was penetrated. Additional water was encountered in the bituminous claystone and shale at points where the organic content was sufficiently high to make the clay of very low plasticity. Based on a slug test performed in Monitoring Well G-02, the gross hydraulic conductivity of the green shale was measured to be about 4×10^{-6} cm/s.

The red shale unit is much more uniform than the green shale unit and is distinguished by its color, its medium plasticity, and the absence of calcite either as fossils or as

cements. Due to the absence of calcite and the medium plasticity, groundwater flow most likely occurs by means of molecular diffusion and limited fracture flow. In clays of medium plasticity, fracture flow is limited somewhat by the tendency of the clays to swell slightly in the presence of fresh water.

The limestone unit is about 50 ft thick and is believed to underlie the main plant area of OU1. This limestone was encountered only in Boring G-01 but was observed in an outcrop along the bluffs of the Little Vermilion River (see east-west cross-section, Figure 3). Except for fractures, the limestone unit is impermeable. Although significant fractures were observed within the limestone, they were present at a relatively low density (approximately one fracture every 30 to 100 ft along the face of the outcrop). This low density of fractures indicates a low transmissivity for the limestone unit. No karst development was observed.

Pleistocene Deposits: The Pleistocene Series is confined to the northeast corner of the main plant area, where it forms a layer up to approximately 20 ft thick. The Pleistocene Series consists of the following lithologies: (i) coarse till; (ii) fine till; and (iii) silty clay.

In all three types of Pleistocene deposits, groundwater flows through intergranular pore spaces, with the hydraulic conductivity determined by the size and abundance of the pores. The coarse till, which has a matrix of sand and little or no silt and clay, is characterized by a moderately high hydraulic conductivity. In Monitoring Well G-04, the hydraulic conductivity of the coarse till was measured to be approximately 2.7×10^{-3} cm/s.

The silty clay and fine till are estimated to have low to very low hydraulic conductivities on the basis of their fine grain size. Because the matrix of the fine till and the silty clay deposits are of low plasticity, low-rate intergranular flow should dominate. Because of the extremely poorly sorted (very well-graded) nature of the fine till, the amount of intergranular space available for flow should be very low, further reducing the hydraulic conductivity of the fine till deposits.

Holocene Alluvium: Alluvial deposits appear to be confined to the valley of the Little Vermilion River, and are believed to consist mainly of loose silty sand and soft sandy silt. The depth of the alluvial deposits is unknown. The alluvial deposits are believed to be of Holocene age (within the past 10,000 years), but a Pleistocene component may also be present. In the section of the river that flows by OU1, the alluvial deposits appear to have been buried by deposits of slag.

Fill Deposits: Fill deposits were observed to cover large areas of OU1. Significant deposits were found mainly in the central part of the main plant area where they constitute the infill material for the former gully. The fill deposits are both complex and very significant to the flow and potentially to the quality of groundwater. In general, the following types of fill were observed during this site investigation: (i) soil fill; (ii) sinter; and (iii) slag.

- **Soil Fill** - Soil fill consists primarily of reworked Pennsylvanian shale. In general, the reworked shale appears to have been derived from residual soil developed in the top of the calcareous green shale, as well as from unweathered shale and siltstone. The reworked shale is characterized by a loosely compacted jumble of shale and siltstone clods with a small amount of miscellaneous fill material. In addition to the reworked shale, the following other types of fill soils were identified: (i) sediment from the former pond that appears to have formed in the gully and lies beneath the reworked shale in Borings G-05, C-3, and possibly C-10; (ii) structural fill associated with the ICCR grade; (iii) miscellaneous shallow fill and road gravel; and (iv) the compacted clay liner constructed for the emergency storage area. In the reworked shale deposits, groundwater most likely flows primarily between large clods of reworked shale and secondarily within the weathered clods of shale. The poorly compacted nature of the deposit gives the reworked shale a coarsely granular texture, similar to the coarse till. Based on a slug test conducted in Monitoring Well G-05, the hydraulic conductivity of the reworked shale deposit was found to be about 2.0×10^{-3} cm/s.
- **Sinter Fill** - Sinter, in the context of zinc production, is an intermediate product consisting of agglomerated zinc oxide. Sinter is produced when zinc sulfide ore

is roasted, which causes the sulfur to be driven off and the zinc to oxidize. The sinter identified in the fill deposits is presumed to have been off-specification material. Where encountered in the borings, the sinter consisted of black, loose granular material, the size of medium sand. The hydraulic conductivity of the sinter is most likely slightly greater than the reworked shale or the coarse till.

- Slag Fill - Slag is the recrystallized or vitrified silicate and oxide residue from the production of metal from ore. Typically, and as observed at OU1, slag ranges in color from moderate red to blackish red and has a highly porous, cindery, vesicular texture similar to scoriaceous lava rock. Much of the slag appears to have become welded into large blocks by its own heat prior to and during deposition. Slag deposits observed in outcrops of OU1 were extremely porous with large, interconnected voids on the order of 0.3 to 1.0 ft across. The hydraulic conductivity of the slag deposits is believed to be very high, at least locally within the deposit.

2.6.3 Hydrogeology

2.6.3.1 Regional Hydrogeology

Aquifers within north-central Illinois are represented by sands and gravels occurring within the glacial drift, as well as permeable bedrock formations, principally sandstones and dolomites. The City of LaSalle has a wellfield approximately 0.6 mile south of OU1, within the Illinois River Valley. The water supply wells are screened in glacial sands and gravels at depths ranging from 60 to 70 ft below land surface (BLS). The City of Peru operates a municipal wellfield approximately two miles northwest of the Carus Chemical Company manufacturing facility. Water is obtained from lower Paleozoic formations at depths greater than 2,000 ft BLS.

2.6.3.2 OU1 Hydrostratigraphy

The main plant area is dominated by an erosional gully that is filled with loosely compacted soils and slag. The erosional gullies were formed by glacial scouring during the Pleistocene Epoch, about 20,000 years ago. Around this time, the Little Vermilion Gorge was scoured nearly removing all glacial deposits from OU1. Stream and

floodplain sediments were deposited in the Little Vermilion Valley. The fill deposits form the upland fill aquifer system which overlies a bedrock confining layer. The slag berm along the eastern side of the main plant area seems to have been constructed across the mouth of the gully. Infilling of the gully most likely began following construction of the slag ridge. A shallow pond appeared in the gully, causing deposition of soft alluvial soils. Based on historic maps of the site, infilling of the gully was completed by 1928.

The deposits beneath the main plant area can be divided into five hydrostratigraphic units based on the magnitudes of their permeabilities and the nature of their pore structures. The hydrostratigraphic units are outlined below. Hydraulic conductivity values are provided in the Phase I Site Investigation report (Geosyntec, 1994).

- Unit I consists of slag deposits, with very high permeability and very large pore spaces. The hydraulic conductivity of Unit I is estimated to be on the order of 1×10^{-1} cm/s.
- Unit II consists of fill deposits and coarse till, with the moderately high permeability and coarse, intergranular texture (considering clods of reworked shale as large grains). The hydraulic conductivity of Unit II is estimated to be on the order of 1×10^{-3} to 3×10^{-3} cm/s.
- Unit III consists of the upper two-thirds of the green shale unit and includes residual soil and weathered shale, the coal, and the bituminous gray claystone and shale. Flow in Unit III appears to occur primarily through fractures in the shale and coal. The hydraulic conductivity of Unit III is estimated to be on the order of 3×10^{-6} to 1×10^{-5} cm/s.
- Unit IV consists of the fine till deposit, with its very low hydraulic conductivity and intergranular flow. According to Freeze and Cherry (1979), fine tills may have hydraulic conductivities as low as 1×10^{-8} to 1×10^{-10} cm/s.
- Unit V consists of the lower part of the green shale and the red shale, which together form the lower confining layer for the shallow upland fill aquifer

system. Unit V may have a hydraulic conductivity somewhat higher than Unit IV due to the potential for molecular diffusion and fractures within the shales.

Hydraulic testing was conducted during previous investigations. These results were discussed relative to specific stratigraphic units earlier in the Stratigraphy section, as applicable, and are summarized in Table 1.

2.6.4 OU1 Flow Systems

2.6.4.1 Overview

The purpose of this section is to describe the nature of the groundwater flow systems beneath OU1 in order that information on groundwater quality can be evaluated properly with respect to potential environmental risk. The flow and chemical composition of groundwater beneath the main plant area are strongly influenced by the geometry and composition of fill deposits and bedrock. A separate flow system exists for the slag pile in OU1. In order to understand the complex relationships between the various layers of bedrock and fill deposits, a description of the OU1 geology and a narrative on the geologic history of OU1 was provided earlier in this document.

2.6.4.2 Description of the Main Plant Area Flow System

The shallow groundwater flow system in the main plant area is comprised of two main units. The most prominent water-bearing unit is associated with the erosion gully that was filled with loosely compacted soils and slag, corresponding to hydrostratigraphic Units I and II. A secondary unit is associated with the coarse till (Pleistocene) deposits confined to the northeast portion of the main plant area. The water-bearing unit associated with old erosion gully (referred to as the fill aquifer) is bounded below by the red shale and limestone, which are assigned to hydrostratigraphic Unit V and which form the lower confining layer. The fill aquifer is bounded laterally on the north, west, and south by the green shale unit, which forms hydrostratigraphic Unit III. On the northeast, the fill aquifer is bounded by the fine till, which forms Unit IV. The lower and lateral boundaries of the fill aquifer are considered to correspond to the contact between the fill and green shale.

The secondary water-bearing element of the shallow flow system is present in the coarse till deposits in the northeastern corner of the main plant area. The coarse till is assigned to hydrostratigraphic Unit II and hereinafter is considered the coarse till aquifer.

The principal sources of water for the fill aquifer are direct infiltration of precipitation, and to a limited extent, fugitive loss of non-contact cooling water and storm water run-off from the plant sewer system. Direct infiltration appears to be responsible for the water present in the coarse till aquifer and in the green shale unit in the northeastern portion of the main plant area.

2.6.4.3 Description of the Slag Pile Flow System

The slag pile area is believed to be underlain by a single shallow flow system consisting of two components. Hereafter, this will be referred to as the Little Vermilion Flow System. The main component of the Little Vermilion Flow System consists of the river channel, the alluvium, and the slag in the lower portions of the valley. Observations made during previous investigations suggest a common southward-flowing gradient in these deposits with gradual convergence of flow into the river. The other component of the Little Vermilion Flow System is believed to consist of flow from the upland areas directly toward the river under relatively steep hydraulic gradients.

The evidence presented above suggests that water within slag pile area will generally be discharged at the southern end of OU1 through either the channel or alluvium of the Little Vermilion River.

2.6.4.4 Direction and Rate of Flow

Water level elevations measured in monitoring wells at OU1 suggest that shallow groundwater flows to the east-southeast towards the Little Vermilion River. Groundwater in the main plant area generally flows eastward toward the Little Vermilion River. The groundwater flow from the Carus main plant area appears to be channelized into a narrow area in the vicinity of Soil Boring G-01 likely as a result of the configuration of the bedrock surface and the nature of the fill and glacial deposits.

The direction of flow in the upland fill is shown on the potentiometric surface map (Figure 4). This map also shows the four hydrostratigraphic units which are present above the lower confining layer (Unit V). The direction of flow is to the east, toward the Little Vermilion River.

Generally, the potentiometric surface flattens away from the groundwater mound and steepens toward the steep hillside leading down to the Little Vermilion River. The potentiometric gradient in the slag (Unit I) is very flat. This flatness is reflective of the high hydraulic conductivity of the unit as opposed to the absence of flow. The potentiometric gradient in the green shale (Unit III) away from the plant is fairly flat. This is reflective of the low rate of recharge and discharge and of the flat topography. In the spring, when infiltration is high due to rain and snowmelt and evapotranspiration is low, the potentiometric gradient in Unit III is expected to be significantly higher.

Darcy's Law expresses an ideal relationship between the potentiometric gradient, the hydraulic conductivity, and the rate of groundwater flow under non-turbulent conditions:

$$Q = KAi$$

where Q is the rate of flow, K is the hydraulic conductivity, A is the unit cross-sectional area perpendicular to flow, and i is the hydraulic gradient. By dividing A into Q, the Darcy Flow Velocity (V) is obtained. The Darcy Flow Velocity indicates the general rate of water flow through a large volume of rock, as opposed to specific rates of flow through individual pores. Groundwater flow rates were estimated for Units II and III using this relationship as follows:

- At Monitoring Well G-02, the potentiometric gradient in Unit III is mapped as 8 percent (see Figure 4) and the hydraulic conductivity was estimated by slug testing to be about 4.1×10^{-6} cm/s. From these values, the overall rate of groundwater flow at Monitoring Well G-02 should be approximately 0.3 ft/yr.
- At Monitoring Well G-04, the potentiometric gradient in the coarse till aquifer (Unit II) is mapped at 3 percent (see Figure 4) and the hydraulic conductivity

was estimated by slug testing to be about 2.7×10^{-3} cm/s. From these values, the overall rate of flow at Monitoring Well G-04 should be approximately 78 ft/yr.

- At Monitoring Well G-05, the potentiometric gradient in the shallow fill aquifer (Unit II) is mapped at 4 percent (see Figure 4) and the hydraulic conductivity was estimated by slug testing to be about 2.1×10^{-3} cm/s. From these values, the overall rate of flow at Monitoring Well G-05 should be approximately 90 ft/yr. Based on this information, the average groundwater flow rate for Unit II is 84 ft/yr.

3. CURRENT UNDERSTANDING OF THE NATURE AND EXTENT OF CONTAMINATION

3.1 Introduction

This section briefly summarizes the TLR's review of previous OU1 investigations. The TLR discusses the site characterization findings in detail, with an independent review of the results of each investigative scope. In contrast, for the purposes of this Work Plan, all data will be treated as one comprehensive data set and will be further reviewed as such in Section 4. Section 3 primarily describes the chronology and rationale of each historical investigative scope with a brief, overall summary of all findings as discussed in the TLR. For a detailed discussion of each investigative scope and a detailed review of characterization data tables, the reviewer is referred to the TLR. In Section 4, a more advanced analysis of the chemistry data is presented to support the development of a CSM and a strategy for RI characterization of OU1.

3.2 Chronology and Rationale of Historical Investigations

Soil, slag, groundwater, surface-water, and sediment samples have been collected at OU1 as part of prior investigations conducted by Geosyntec and Illinois Environmental Protection Agency (IEPA). Figures 5a and 5b present an overview of the investigations by showing the locations of sampling efforts associated with these investigations. The investigations and their purpose are described as follows:

- **Preliminary Assessment Report (Carus):** The CERCLA Preliminary Assessment Report was prepared by the IEPA following placement of the Carus main plant area in the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) in May 1991. The purpose of the Preliminary Assessment Report was to conduct an initial evaluation of the site and recommend to the USEPA a priority for conducting additional investigations as part of the CERCLA process. No environmental samples were collected during this effort.

- **Screening Site Inspection (Carus):** A CERCLA Screening Site Inspection (SSI) was conducted in 1991 by the IEPA for the Carus main plant area, which is now included in OU1. The purpose of the SSI was to: (i) collect additional data in order to perform a preliminary Hazard Ranking System (HRS) site score; (ii) establish priorities among sites most likely to qualify for the National Priorities List (NPL); and (iii) identify the most critical data requirements for any further investigation, if necessary. The scope of work conducted as part of the SSI included the collection of four surface soil samples, one background surface soil sample, eight sediment samples, three groundwater samples from on-site monitoring wells, and one background groundwater sample.
- **Preliminary Site Investigation (Carus):** The Preliminary Site Investigation (PSI) was conducted by Geosyntec at the Carus main plant area in October 1992. The objectives of the PSI were to: (i) assess chemical constituents contained within the soil, sludges, and groundwater; (ii) examine visually the subsurface materials; (iii) collect soil samples for laboratory analysis; and (iv) install additional groundwater monitoring wells. The scope of work conducted as part of the PSI included the following: (i) advancement of 16 soil borings for visual classification and analytical sampling; (ii) installation of two groundwater monitoring wells; (iii) collection and laboratory analysis of soil and sediment samples from the Little Vermilion River and the holding pond; (iv) collection of five unfiltered groundwater samples from the two newly installed monitoring wells and three existing wells (those sampled during the IEPA SSI in November 1991); (v) measurement of water levels in monitoring wells to evaluate groundwater flow; and (vi) performance of a single well aquifer test (slug test) in a monitoring well located within the slag-deposit area east of the railroad embankment.
- **1993 Investigation (Carus):** The investigation in November of 1993 was conducted by Geosyntec at the Carus main plant area to: (i) evaluate the constituents at three locations of the site, including concentration and extent; (ii) assess the data to more accurately depict the hydrogeology; (iii) investigate and identify potential migration pathways; (iv) obtain the data necessary to develop an action plan; and (v) satisfy requirements of the Illinois Pre-Notice Site

Cleanup Program. The scope of work conducted as part of the November 1993 investigation included the following: (i) advancement of 18 soil borings; (ii) completion of three of the soil borings as groundwater monitoring wells; (iii) performance of a water supply well exposure survey; (iv) evaluation of existing groundwater monitoring wells; (v) slug testing; (vi) water level measurements; (vii) soil sampling and analysis; (viii) surface-water sampling and analysis; and (ix) groundwater sampling and analysis. The water supply well exposure survey included the following activities: (i) conducting interviews with various individuals who were familiar with water use in the area (including the Mayor of LaSalle, the City Engineer, and the Director of Public Works); (ii) reviewing utility system maps; and (iii) evaluating well construction reports.

- **1994 Investigation (Carus):** Geosyntec continued its investigation in 1994. The purposes of the 1994 investigation included: (i) characterization of the nature and extent of chemical constituents in the portion of the slag pile in OU1 on Carus property; (ii) evaluation of the impacts on groundwater and the Little Vermilion River; (iii) identification of the potential sources of any such impacts; and (iv) satisfaction of the requirements of the Pre-Notice Site Cleanup Program. The scope of work included the following elements: (i) a site inspection; (ii) evaluation of the holding pond; (iii) meteorological assessments; (iv) surface-water sampling in the Little Vermilion River and analysis; (v) sediment sampling and analysis in the Little Vermilion River; (vi) advancement of 18 soil borings, and soil sampling and analysis, principally in the slag pile; (vii) installation of 10 piezometers; (viii) water-level measurements; (ix) slug and pump tests; and (x) groundwater sampling and analysis.
- **Preliminary Assessment Report (M&H Zinc Company Site):** The CERCLA Preliminary Assessment Report was prepared by the IEPA in 1994 following the CERCLA Screening Site Inspection of the Carus Site conducted in November 1991, at which IEPA noted large piles of slag material. The report provided an operational and regulatory history of the M&H Zinc Company and summarized the findings of the site visit. Groundwater, surface-water, air, and soil migration pathways were discussed. No environmental samples were collected during this effort.

- **Integrated Site Assessment (M&H Zinc Company):** The CERCLA Integrated Site Assessment was conducted in December 1993 by IEPA to “help characterize the nature of sources, and to determine if these sources had impacted nearby human populations or the environment”. Investigative activities of the IEPA sampling team included: (i) collection of four sediment samples from the Little Vermilion River; and (ii) collection of eight soil samples. Of the eight soil samples, three were collected from the slag pile located within OU1. In addition, thirteen soil samples were collected off-site at residences near the Site.

3.3 Summary of Investigative Findings

The following conclusions are based on all of the data collected and observations noted during the investigations conducted to date on OU1:

- Slag material associated with past smelting operations (M&H Zinc Company) was placed within the Little Vermilion River Valley and encroaches upon and has changed the course of the Little Vermilion River. The M&H Zinc Company generated and placed these materials prior to acquisition of the property by Carus.
- Slag material (and groundwater within the slag) is likely to be at least partially in direct contact with the surface water in the Little Vermilion River. The groundwater within the slag discharges to the Little Vermilion River.
- Groundwater within the slag and the alluvium of the Little Vermilion River is isolated from the deeper aquifer by more than 1,000 ft of alternating layers of low permeability shales and limestones. This groundwater is distinct from the shallow perched groundwater in the Carus manufacturing area.
- The sinter and slag areas are the primary sources of chemical constituents in the environment at OU1. The data indicate that metals are more broadly distributed and at higher concentrations relative to media screening values than are organic chemicals whose presence is sporadic.

- Impacts to soils located within OU1 may include arsenic, chromium, iron, lead, and manganese (based on totals data), as well as zinc and cadmium (based on Toxicity Characteristic Leaching Procedure (TCLP) data).
- The sinter and slag source areas appear to have had only a very minor impact on groundwater at the site due to the low leaching potential and immobility of the constituents bound in the sinter/slag matrix. The sand and gravel aquifer below the site has only been minimally affected.
- Relatively minor impacts to groundwater quality with respect to human health screening criteria have been detected in monitoring wells screened within the slag pile. These impacts primarily include aluminum, arsenic, cadmium, chromium, iron, lead, manganese, nickel, and zinc. These elevated concentrations may be associated with turbidity of groundwater samples, and may not reflect the mobility of the constituents in groundwater.
- An isolated area of elevated levels of benzene, toluene, ethylbenzene, and xylene (BTEX) in groundwater were identified (November 1993) in the extreme northeast corner of the Carus main plant area. These impacts are believed to be associated with miscellaneous spills from a former above-ground storage tank.
- Elevated levels of metals are present within the slag. From the standpoint of the potential for exposure of chemicals to humans through direct contact, the slag pile is located in a low-traffic area and site access is controlled by fencing and periodic patrols by off-duty police officers.
- Elevated levels of organics and metals were measured within sediment samples collected from the holding pond. Results for these samples were evaluated with respect to ecological screening criteria. Impacts to sediment include elevated levels of arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, acetone, anthracene, arochlor 1254, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, fluoranthene, phenanthrene, and pyrene. The polynuclear aromatic hydrocarbons (PAHs) may

be related to the mining and use of coal historically in industrial operations at and surrounding the site.

- Elevated levels of metals were measured within some of the surface-water and sediment samples collected from the Little Vermilion River. Results for samples collected in the river were evaluated with respect to ecological screening criteria. Impacts to sediment include elevated levels of arsenic, cadmium, copper, cyanide, lead, mercury, nickel, and zinc. Impacts to surface water include elevated levels of cyanide, iron, lead, mercury, and zinc. The types of metals and the concentrations observed may indicate potential impacts to the Little Vermilion River from the presence of slag. The RI/FS will evaluate the potential for interaction between the slag pile and the river, as discussed in Section 7 of the Work Plan.

4. CONCEPTUAL SITE MODEL

4.1 Introduction

Historical data indicate that both organic and inorganic constituents present in site media may pose a risk to human and/or ecological receptors. While both broad classes of constituents will be investigated as part of the RI/FS, it is evident from the data summary discussed in Section 3 that metals are of greater significance than organics. The detection of all 23 Target Analyte List (TAL) metals in site media is complicated by the fact that the characteristics of transport and bioavailability of metals will vary considerably from one metal to another. In some cases, two metals will undergo similar changes in transport characteristics when subjected to a given geochemical change, whereas in other cases, two metals may undergo opposite behavior and hence be in conflict. A thorough understanding of the implications of baseline metals presence is not possible without a consideration of the geochemical mechanisms that control metals fate and transport. Even more importantly, any consideration of potential remedial actions must consider the effect of geochemically-driven changes to metals behavior that may, in turn, stem from the remedy.

Given the wealth of existing data and the complexity of metals geochemistry and risk assessment, Section 4 draws on a more detailed and structured method of data analysis to focus consideration on the most important site concepts by: (i) seeking the highest priority constituents of potential concern (COPCs); and (ii) identifying dominant trends of constituent presence and transport characteristics. Key components of this analysis include the following:

- development of a physical CSM that graphically presents the interrelationships between process areas, OU1 media, transport mechanisms, and potential receptors;
- submedia analysis, whereby analytical data from a given OU1 medium (e.g., solid samples) are screened against risk-based standards according to medium subcategories (e.g., fill, gravel, surface soil, rock, and slag) to examine in more detail the effect of sample matrix on concentration;

- preliminary metal priority ranking, whereby the results of the submedia analyses are used to identify the most significant metal constituents from the perspective of human health and ecological risk;
- preliminary discussion of metals geochemistry, in which the high-priority metals described above are examined with respect to geochemical characteristics to identify the most critical factors controlling metals fate and transport;
- a discussion of the occurrence of organic constituents of concern; and
- a discussion of transport pathways relevant to the RI/FS risk assessment.

Note that the submedia analysis and priority ranking for metals presented herein does not replace formal data screening for the human health and ecological risk assessment proposed in Section 7, nor is it used to prematurely reduce any investigative scope. Instead, it is presented to provide a framework for priority ranking of metals to be used throughout the RI/FS to focus higher-level analysis, including geochemical modeling, toxicological literature review, and detailed remedy considerations, on those metals that present the greatest overall risks on site. Due to the ubiquity and background presence of numerous metals as well as their potentially conflicting geochemical behavior, it is anticipated that remedy decisions will require trade-offs among the degree of management of individual metals. Hence, the establishment of such priorities to support such decisions may be beneficial as the RI/FS process unfolds.

4.2 Physical Conceptual Model

Figure 6 depicts the current understanding of the interrelationships between the major physical features of OU1 (i.e., the upland process areas, slag pile, and Little Vermilion River). This figure conveys, in simple terms, the major transport mechanisms for the Site. It draws upon the findings of the historical investigations summarized in the TLR, as well as observations from recent site reconnaissance. In evaluating the data from historical investigations, we have grouped the data by medium to support the establishment of priorities for the metals under investigation as part of the RI/FS.

Key conceptual elements that should be noted from Figure 6 are listed below:

- Solid matrices can be divided into several general categories, including surface soil, gravel, fill derived from native material, sinter, slag, and alluvium. Most of these media (a clear exception being the alluvium) are present hydraulically and topographically upgradient of the slag pile; hence, one would not expect that chemical impacts to these media would have resulted from the slag pile.
- A well-vegetated strip of ground is evident in limited areas at the base of the slag pile immediately adjacent to the river. This may be the result of overbank deposits from past flood events. While this does not likely preclude groundwater flux from the slag pile to the river, it does suggest the potential for a geochemical transition zone between the slag and the river. Neither the continuity, thickness, nor chemical characteristics of these deposits are well understood at present.
- Physical transport of sediment and slag within the Little Vermilion River could be a major transport mechanism and should be further investigated during the RI. The River Characterization Program discussed in Section 7.3 of the Work Plan presents a phased approach to evaluate physical transport of sediment and slag within the Little Vermilion River. The first phase of the program includes physical mapping of sediment and slag depositional areas along the site boundary and downstream of the site. The mapping will extend to the confluence of the Little Vermilion and Illinois Rivers. Based on the first phase of sampling, additional phases will be conducted, as necessary, to evaluate impacts from the M&H Zinc Company Site to the Little Vermilion River.

Sediment within the Little Vermilion River may have been impacted by historic operations from the M&H Zinc Company, as well as by slag located within OU1. These sediments may be transported by river flow and eventually redeposited downstream of the site within the riverbed or within floodplain of the Little Vermilion River. Sediment sampling will be investigated in a phased manner during the RI, focusing first on areas near the site, as well as upstream of the site to establish background.

Slag from the slag pile located adjacent to the Little Vermilion River has the potential to erode into the river and be transported downstream. The slag observed within the river varies considerably in size from small slag pebbles to large boulders several ft in diameter. Once slag has eroded into the river, the distance the slag travels downstream from the point of entry is influenced by many factors, including particle size and river velocity. Larger slag boulders are anticipated to be located closer to the site than fine-grained sediment. Smaller particles can be more easily transported downstream. During the initial phase of the River Characterization Program, the deposition of slag within the Little Vermilion River will be mapped to the confluence with the Illinois River.

The implications of these conceptual elements are discussed in subsequent portions of Section 4. There are two additional issues related to the physical CSM, including: (i) drinking water exposure pathways; and (ii) overland surface-water flow.

Drinking Water Exposure Pathways: This issue was explored in the 1993 Investigation (Section 3). In concept, there are three possible pathways to drinking water exposure: (i) private wells screened in Pleistocene till; (ii) public supply wells for the City of Peru screened in lower Paleozoic formations; and (iii) public supply wells for the City of LaSalle screened in Illinois River alluvium.

Based on the results of the water supply well exposure survey, it was concluded that there is little potential for human exposure to groundwater through private wells. This inference is based on the distance of private wells from the Carus main plant area (within two miles of the site, there were no known wells located within the sands and gravels of the Pleistocene drift) and the differentiation between the hydrostratigraphic units that supply the private wells from those of the OU1 flow system. Specifically, private wells at distances greater than two miles from the site are supplied by water withdrawn from sands and gravels within the Pleistocene drift. While generally regionally extensive, it is largely absent from OU1 due to post-Pleistocene erosion, with the exception of an isolated remnant present in the northeastern corner of the Carus main plant area. The only areally extensive unconsolidated medium at the Carus plant is residuum developed from the weathering of exposed Pennsylvanian bedrock; aquifer hydraulic testing demonstrated that the hydraulic conductivity of the residuum is two

orders of magnitude less than that of the Pleistocene deposits. Hence, it is unlikely to serve as a significant transport mechanism toward private wells. In addition, a memorandum of understanding between IEPA and the City of LaSalle entered into in 2002 and related City of LaSalle ordinances (Ordinance No. 1084, adopted 1985, Ordinance No. 1474, adopted 1994, and Ordinance No. 1755, adopted 2002) prohibit the drilling of any new water supply wells in areas within 300 ft of a city public water supply system water main.

It is IEPA policy that such ordinances can be used as an institutional control if either of the following conditions is valid: (i) contamination will remain within the geographic extent of the area governed by the ordinance, or (ii) the ordinance is effective throughout a 2,500 ft buffer from a site. To assess the validity of this condition, Figure 7 presents a comparison of the extent of OU1 and the LaSalle corporate limits as provided by the City of LaSalle's website. A 2,500 ft buffer around the perimeter of OU1 is shown.

Figure 7 indicates that four parcels of unincorporated land lie within the 2,500 ft buffer of OU1. However, three of the four parcels are located east of the Little Vermilion River, across the river from the site source areas. This suggests that a groundwater divide is present between the site and the unincorporated areas. The fourth area is on the same side of the river as OU1 but is located approximately 3,000 ft upgradient of OU1.

Based on these analyses, it is reasonable to conclude that the LaSalle groundwater ordinance can be used for institutional controls to protect drinking water receptors.

The City of Peru supply wells are screened in an interval approximately 2,000 ft below the shallow zones of impacted groundwater in OU1. As discussed in the 15 December 2006 OU1 scoping meeting, this does not appear to be a complete pathway.

The Illinois River alluvium that serves the City of LaSalle supply wells may be in contact with Little Vermilion River alluvium at the Site; hence, this pathway may be viable, although dilution is likely to play a significant role as the groundwater within the Little Vermilion River alluvium flows into that of the Illinois River.

Overland Surface-Water Flow: Surface runoff water can pick up soil (or slag) particles and transport these in overland flow for deposition at a lower land elevation or deliver sediment to receiving waters, such as the Little Vermilion River. Surface runoff water can also pick up dissolved parameters from contaminated soils and deliver impacted water to receiving waters as a nonpoint source of pollution. A land area which produces runoff draining to a common point is called a watershed. A surface-water basin analyses, as described in Section 7.8 of the Work Plan, will be conducted during the RI to evaluate contributing areas and drainage pathways for OU1 and OU2 as potential physical transport mechanisms of concern at the site. Site reconnaissance indicates that there are limited areas within OU1 where surface water accumulates due to poor drainage or topography. One exception is noted to the north of the emergency bypass pond, and this area will be investigated during the RI.

4.3 Submedia Analysis and Preliminary Metals Priority Ranking

In order to more precisely understand the nature of potential source areas, solid matrix and groundwater data were categorized by submedia to the greatest extent possible through a review of boring and well installation information. Samples were categorized as one of eight possible submedia (alluvium, fill, road gravel, shale, sinter, slag, surface soil¹, and till) based on the submedium sampled (in the case of solid samples) or the submedium in which a monitoring well is screened (in the case of groundwater samples.) Using these categories, the analytical data were screened against risk-based standards with summary information computed for each submedium and screening scenario. As indicated in the introduction, the screening is not performed to determine COPCs for the upcoming risk assessment or lead to premature risk management decisions; it is only performed to support the preliminary determination of priorities for metals. When the baseline human health and ecological risk assessments are performed, all metals and all nonmetals will be treated with equal weight in the screening stages. Tables 2a through 2d present the results of the submedia analysis.

The following four bullets present the six screening scenarios considered:

¹ Surface soil was used for IEPA SSI samples for which the soil type is unknown.

- **Solid Matrix (soil, slag, etc.):** Human health scenario using Region 9 Industrial Preliminary Remedial Goals (PRGs) and ecological scenario using Region 5 Ecological Screening Levels for soil;
- **Groundwater:** Human health scenario using Region 9 PRGs for tapwater and ecological scenario using Region 5 Ecological Screening Levels for surface water with a 10 x dilution factor²;
- **Sediment:** Ecological scenario using Region 5 Ecological Screening Levels for sediment; and
- **Surface Water:** Ecological scenario using Region 5 Ecological Screening Levels for surface water.

Tables 2a through 2d present the submedia analysis results. Each table cell provides basic summary statistics of the screening of all available data for a given metal in a given submedium against a given screening value (if available). The summary statistics indicate the number of records that exceed the standard, the number of detections, the total number of records, the arithmetic average value, and the maximum value. In addition, the cells are color-coded to give a visual sense of: (i) the risk priority of the submedium; and (ii) how the submedium compares to other submedia for the given metal.

The tables also designate, for each of the six screening scenarios, “high priority” and “medium priority” metals. In general, the designations are correlated with the risk categories. However, in some scenarios, the risk categorization of the slag data with respect to other submedia is considered. If the slag data and several other submedia data are all classed as “higher risk,” then background conditions may play a role in the

² Groundwater data are not commonly screened against ecological screening values; however, this was performed for OU1 due to the focus on potential groundwater discharges from the slag to the river. The groundwater data were screened against Region 5 Ecological Screening Levels for surface water with a tenfold dilution factor applied. This factor is commonly used for screening the groundwater-surface water pathway when evaluating Resource Conservation Recovery Act Environmental Indicators (RCRA EIs.)

presence of the metal; in such cases, the metal is deemed medium priority. While this does not constitute a background assessment in the formal sense, it is useful in the planning stages of the RI/FS to focus the attention on the metals that most clearly stem from the slag.

Table 3 summarizes the priority designations for each of the 23 TAL metals in all six risk scenarios considered. The priority designations for each metal are summed across all six scenarios to compute an overall priority score; these overall scores are used to rank the 23 metals from the standpoint of overall priority. The rankings are shown on the right side of the table. The top 15 metals on the list, in decreasing order of priority, are zinc, lead, mercury, arsenic, cadmium, nickel, chromium, copper, manganese, silver, antimony, beryllium, iron, selenium, and thallium.

Figures 8a through 8o have been prepared to present multimedia data for each of the 15 metals identified. The figures present data in all media (i.e., solid, groundwater, sediment, and surface water) for a given metal on one figure. TCLP data are also included where available. The figures do not depict vertical variability; instead, they show the maximum value detected at a given sampling location. The figures are designed to condense a considerable amount of data drawn from multiple media for a given metal into one comprehensive figure. As an example of how to interpret the figures, the reviewer is referred to Figure 8o for zinc. The location P-1 at the northern end of the slag pile has data for soil, groundwater, and TCLP sampling. The soil data are represented by the orange symbol at the lower right corner. The legend indicates that the soil concentration is in the range of 1,010 to 23,000 mg/kg (the actual maximum at that location is 8,860 mg/kg). The groundwater data are represented by the lower left corner of the symbol; the legend indicates that the concentration is in the range of 501 to 831 mg/L (the actual value is 831 mg/L). Finally, the red diamond in the middle of the symbol indicates that the TCLP concentration is in the range of 101 to 662 mg/L (the actual value is 662 mg/L).

It should be noted that the data screening and priority ranking method described in this section has not been performed to prematurely eliminate any metals from consideration. All TAL metals will be included in the analytical testing program for the RI/FS and will be duly considered during risk assessment. Instead, the priority ranking process is

useful for Section 4.4, in which the effects of geochemical conditions on the 15 priority metals are discussed.

4.4 Discussion of Metals Geochemistry

As briefly noted in Section 4.1, the processes that dictate metals fate and transport are complex and vary markedly from one metal to the next. In many cases, metals behavior may be in conflict, whereby conditions that promote the attenuation of one metal may further mobilize a different metal. A key component of the OU1 RI/FS entails developing a thorough understanding of the transport characteristics of metals. The conceptual model development, refined data screening, and priority determination discussed in the previous sections were performed in part to simplify, to the greatest extent possible, the range of metals transport considerations by focusing attention on the most significant metals. This section provides a detailed discussion of the geochemical processes that affect the mobility of the 15 priority metals identified in Section 4.3.

4.4.1 Characteristics of Individual Metals

This section provides a description of the general behavior of the 15 aforementioned metals. The effects of numerous factors are noted, including the following:

- pH and oxidation-reduction potential (ORP) (i.e., Eh or redox conditions), commonly referred to as the “master variables” due to their broad-ranging effects on metals mobility;
- multiple valence states (e.g., trivalent and hexavalent chromium);
- the presence of anions, such as carbonates, sulfide, sulfate, and chloride;
- the status of the metal as either a cation or anion (the latter condition tends to increase mobility);
- the presence of organic matter; and
- interactions with other metals, chiefly iron, manganese, and aluminum.

Most of the background information is provided by Adriano (2001).

4.4.1.1 Antimony

Antimony is commonly associated with nonferrous deposits and is emitted to the environment during the smelting of these ores. Antimony exhibits similar geochemical behavior to that of arsenic. Therefore, it is more mobile under reducing conditions as well as higher pH conditions. It is furthermore mainly associated with iron and aluminum oxides and oxyhydroxides and forms stable sulfide compounds.

4.4.1.2 Arsenic

Arsenic is a redox-sensitive metalloid (i.e., it has properties of both a metal and a non-metal). In its reduced form (i.e., arsenite(III)) arsenic is more mobile and more toxic than in its oxidized form (arsenate(V)). Arsenate(V) is generally better-retained by soil surfaces than arsenite(III). Reducing conditions also lead to the reductive dissolution of iron and manganese oxides and oxyhydroxides, which can lead to arsenic mobilization. Unlike many trace metals, arsenic (in the form of arsenate(V)) is generally more soluble and mobile under alkaline conditions. Similar to other trace elements, arsenic is more mobile and bioavailable in sandy soils compared to finer-textured soil.

4.4.1.3 Beryllium

In the natural environment, beryllium is mainly found in association with silicate minerals. Coal combustion is the primary environmental source of beryllium. It occurs as the divalent cation Be^{2+} , which readily complexes with organic matter. In this form, it is relatively immobile and may accumulate in surface soils. However, its inorganic complexes, such as BeCl_2 and BeSO_4 , are fairly soluble and mobile. Under alkaline conditions, BeO is the main stable species. Like many other trace metals, beryllium is more mobile under acidic conditions.

4.4.1.4 Cadmium

Similar to lead, the pH of soils, sediments, or groundwater is the single most important factor affecting cadmium mobility. Acidic conditions favor cadmium solubility and

bioavailability. Higher pH conditions favor increased adsorption of cadmium to oxides and oxyhydroxides of iron, manganese, and aluminum, as well as to clay minerals and organic matter. These conditions are also conducive to the formation of sparingly soluble carbonates, hydroxides, and phosphates. While cadmium is not a redox-sensitive metal, low redox potential generally leads to the formation of insoluble cadmium sulfides. Cadmium forms a variety of complexes and chelates. If organic acids (e.g., humic and fulvic acids) are naturally abundant, cadmium can be quite mobile due to the formation of soluble metal-organic complexes. However, under non-acidic conditions and the presence of solid organic matter, cadmium is generally quite immobile in the terrestrial environment.

4.4.1.5 Chromium

Chromium is a redox-sensitive trace metal. Its solubility, mobility, and toxicity are mainly affected by pH and redox potential. Chromium essentially behaves in an opposite manner compared to arsenic (i.e., it is more toxic and mobile under oxidizing conditions). While the reduced form Cr(III) is relatively benign, Cr(VI) is fairly mobile and toxic. These two oxidation states are the main forms of chromium in the natural environment. Reduction of Cr(VI) to Cr(III) appears to occur mainly under acidic conditions. Under very acidic conditions (i.e., around pH 2.5), Cr(III) is fairly mobile, while it precipitates out at pH conditions above 4.5. In comparison, hexavalent chromium, appears to be more mobile under neutral to alkaline conditions, since Cr(VI) adsorption decreases with increasing pH. Hexavalent chromium is present as an anion (thus the higher mobility), while Cr(III) exists mainly as a cation. Soluble organic matter can serve as a chelating agent for Cr(III), as well as an electron donor for the reduction of Cr(VI). Iron and manganese oxides play an important role in chromium chemistry. Manganese oxides provide both adsorption sites for chromium retardation, as well as serve as electron acceptors to allow the oxidation of Cr(III) to Cr(VI) to proceed.

4.4.1.6 Copper

The mobility of copper is largely dependent on the pH of soils, sediments, and groundwater. Copper solubility and bioavailability is drastically reduced at a pH above

7, while pH conditions below 5 favor copper solubility. Organic matter has a high sorption capacity for copper, which generally limits copper mobility. However, in its dissolved form, organic matter (i.e., organic ligands) can also increase the leachability and transport of copper. Similar to many other trace metals, the amount of oxides and oxyhydroxides of iron and manganese plays an important role in the retention of copper in soils and/or aquifer matrices. Copper can also form sparingly soluble carbonates and hydroxides, and under reducing conditions, copper sulfides.

4.4.1.7 Iron

As previously mentioned, iron and manganese are frequently associated with each other in natural environments. Like manganese, iron is more soluble and mobile in its reduced form (i.e., Fe(II)) than in its oxidized form (i.e., Fe(III)). In its oxidized form (ferric iron, Fe(III)), iron readily precipitates as oxides, oxyhydroxides, and carbonates, which are immobile species. In its reduced form (ferrous iron, Fe(II)), iron is soluble and mobile. However, in the presence of sulfide, iron precipitates as iron sulfides (FeS and FeS₂), which are immobile unless re-oxidized. Quite frequently, high iron concentrations in groundwater may indicate high arsenic concentrations as well, since arsenic gets mobilized through anaerobic dissolution of iron oxides and oxyhydroxides.

4.4.1.8 Lead

The pH of soils, sediments, or groundwater is the single most important factor affecting lead mobility. Acidic conditions favor lead solubility and bioavailability. Higher pH conditions favor the adsorption of lead to oxides and oxyhydroxides of iron, manganese, and aluminum, as well as to clay minerals and organic matter. Furthermore, the formation of sparingly soluble lead carbonates and phosphates under these conditions limits lead mobility. Under very alkaline conditions, which dissolve organic matter, and/or the presence of natural organic acids (e.g., humic and fulvic acids), lead solubility will increase due to the formation of mobile metal-organic complexes. A low redox potential may lead to the dissolution of iron hydroxides, which would result in increased lead mobility, but it may also favor the formation of insoluble lead sulfides (e.g., galena). In general, high lead concentrations are limited to surface soils, and concentrations decrease sharply with depth. Unless surface soils are highly

contaminated, lead is rarely found in dissolved form in groundwater due to its generally low solubility. If detected in groundwater, it is frequently associated with suspended silt and clay particles.

4.4.1.9 Manganese

Manganese is a redox-sensitive trace metal. Its chemical behavior is similar to iron, and the two elements are frequently associated with each other in natural environments. Manganese geochemistry is quite complex; it can exist in several oxidation states, with the oxidation states of II, IV, VI, and VII being the most stable. Manganese minerals are widely distributed, with the most common ones being the oxides, carbonates, and silicates. Divalent manganese (i.e., Mn(II)) is very stable and mobile under acidic conditions, while MnO₂ is stable under more alkaline conditions. Manganese does not form complexes with ligands as readily as other trace elements. The pH is the most important variable affecting manganese mobility. However, the redox potential of a natural matrix is also very important; the reduced form of manganese is more soluble and (bio-)available. Reducing conditions can create toxic Mn²⁺ levels in soils. Under more aerobic conditions, manganese precipitates out as sparingly soluble oxides, oxyhydroxides, and carbonates. Furthermore, manganese is strongly sorbed by organic matter, which also limits its mobility.

4.4.1.10 Mercury

Mercury mobility is strongly affected by pH and redox conditions. Furthermore, mercury undergoes complexation with many organic and inorganic ligands in natural systems. Mercury speciation strongly depends on pH and chloride concentrations. Under acidic conditions and the presence of chloride, the poorly adsorbed mercury species HgCl₂ is predominant. Mercury is also strongly chelated by soil organic matter, which can either lead to immobilization, or to mobilization under conditions that favor the dissolution of organic matter (e.g., high pH conditions). Under low redox conditions, mercury may be immobilized by precipitation of mercury sulfides (e.g., cinnabar). However, under sulfate-reducing conditions, mercury can be methylated, which is the most toxic and bioaccumulative form of mercury.

4.4.1.11 Nickel

As with most trace metals, nickel mobility is mainly governed by pH and its effect on nickel sorption onto oxides and oxyhydroxides of iron, manganese, and aluminum. The pH also influences the precipitation of nickel with other compounds, such as phosphates (e.g., at pH values ≥ 7). Similar to copper and many other trace metals, organic matter has a high sorption capacity for nickel, which generally limits its mobility. However, in its dissolved form, organic matter (i.e., organic ligands) can also increase the leachability and transport of nickel. Under reducing conditions, nickel can form a variety of sparingly soluble sulfides that limit its mobility under these conditions.

4.4.1.12 Selenium

Like arsenic, selenium is a metalloid, and it exhibits similar geochemical behavior to that of sulfur. Selenium mobility is mainly affected by pH, redox potential, and content of organic matter and oxides. Selenium is a redox-sensitive element, and the most important oxidation states are -II, 0, IV, and IV. The most common ions in natural environments are selenite (SeO_3^{2-}) and selenate (SeO_4^{2-}), both of which are oxidized species that are highly water soluble. Selenite is the predominant mobile inorganic form of selenium in humid regions. Its mobility is mainly controlled by adsorption onto hydrous sesquioxides, such as gibbsite and goethite. Selenite is generally better adsorbed than selenate, which renders it less mobile than selenate. Elemental selenium (Se^0) is much less water soluble and mobile than the oxyanions. Elemental selenium is easily oxidized to selenite and further to selenate. Therefore, in well-aerated, alkaline environments, selenium (in the form of selenate) is quite mobile and (bio-)available. The solubility of selenium is low under slightly acidic to neutral conditions.

4.4.1.13 Silver

In natural environments, silver is mainly found as sulfides in association with iron, lead, and gold. While silver is one of the most toxic heavy metals to microorganisms, it is considered relatively harmless in the terrestrial environment since it readily forms insoluble compounds. Silver is most toxic in its ionic form (Ag^+), while it is less toxic when it forms complexes with chloride and dissolved organic carbon (DOC). It forms

very stable complexes with sulfides, halides, and thiosulfates. Within a narrow range of oxidizing conditions (between about +300 mV to +400 mV), Ag^+ is the predominant form across a wide range of pH conditions. Below that redox range, silver is mainly stable in its elemental form (Ag^0) and as sulfides (Ag_2S). High chloride concentrations (e.g., in seawater) generally diminish silver toxicity through the formation of stable AgCl_n complexes.

4.4.1.14 Thallium

The primary oxidation state of thallium is I; however, it can also occur as thallium(III). Its geochemical behavior is similar to alkali metal cations. It is concentrated in certain sulfides, and deposits high in arsenic are often also high in thallium. Most thallium compounds are volatile to a certain degree and tend to be enriched in dust. Thallium is quite toxic to organisms at small concentrations, and there is a potential for thallium to become biomethylated in the environment. Within a soil environment, thallium is not very mobile, and only trace amounts of thallium should be expected in groundwater. Under oxidizing conditions, fairly stable and immobile thallium oxides are formed. In general, thallium will be more mobile and (bio-)available under acidic conditions.

4.4.1.15 Zinc

Zinc mobility and bioavailability is mainly governed by pH. As with many trace metals, zinc solubility is higher under more acidic conditions. Alkaline conditions favor adsorption of zinc to oxides and oxyhydroxides of iron, manganese, and aluminum, as well as to clay minerals and organic matter. Organic matter appears to play a more important role on zinc adsorption as compared to the hydroxides. Under low redox conditions, zinc may form insoluble sulfides. Naturally-occurring chelating agents, such as many organic acids, can increase the solubility and mobility of zinc.

4.4.2 Summary of Geochemical Controls for Priority Metals

Figure 9 presents a summarized schematic chart of the behavior of the 15 priority metals. While the preceding briefings in Sections 4.4.1.1 through 4.4.1.15 indicate that numerous variables play a role in metals mobility and bioavailability, the two “master variables” of pH and ORP have the greatest control. Hence, the generalized behavior of

the 15 metals is displayed as a function of pH and ORP in Figure 9 to graphically depict the general behavior of the metals.

The most striking conclusion that can be drawn from the figure concerns the effect of pH. Acidic conditions exacerbate the impacts of virtually every priority metal listed. The effect of ORP is less dominant and tends to be conflicting. For example, oxidizing conditions tend to mobilize mercury, chromium, silver, and selenium, whereas reducing conditions tend to mobilize arsenic, manganese, antimony, beryllium, iron, and thallium. The remaining five metals (lead, zinc, cadmium, copper, and nickel) are generally insensitive to ORP. It is worth noting that these five metals are some of the highest priority metals observed in historical data.

Figure 10 displays a synoptic series of pH and ORP data in groundwater, measured during the 1994 investigation. It is shown to explore the potential for spatial trends in geochemistry that may control metals mobility. ORP values are generally moderate with few noticeable spatial trends, although a group of three mutually proximal wells (MW-2, P-17, and P-18) at the eastern and northeastern edge of the holding pond suggest a localized area of moderately depressed ORP. The pH values are generally moderate and consistent, with one exception. P-1, an isolated well at the far northern edge of OU1, exhibited an unusually acidic pH of 4.51. The cause of this unusual pH reading has not yet been determined.

The potential importance of pH is, however, illustrated in a review of groundwater data from P-1. Table 4 presents site-wide summary statistics for all groundwater data for eight priority metals for which the groundwater sample from P-1 was tested in 1994. The P-1 results are shown in comparison to the site-wide summary statistics to show how the concentrations compare to other results on-site. The table shows that for three out of eight metals (cadmium, nickel, and zinc, all of which are generally mobilized at low pH), the P-1 concentration is the highest concentration observed on-site to date. A fourth metal, manganese, can be mobilized at low pH and oxidizing conditions (both of which prevail); its concentration in P-1 is the fifth-highest manganese reading in a dataset of 30 well samples. Four other metals (chromium, iron, lead, and mercury) do not exhibit unusually high concentrations; however, their dependence upon pH for mobility varies (e.g., lead is mobilized at low pH, whereas chromium is generally

insensitive to pH). While the behavior of all eight metals in P-1 are not uniform with respect to the expectations for low-pH conditions, in general, the data do strongly suggest that the importance of pH predicted in Figure 9 is borne out by site data.

4.5 Vertical Distribution of Metals in Site Media

Figure 11 presents a three-dimensional view of the distributions of zinc and lead in site media. As demonstrated in the figure, the vertical distributions of zinc and lead are relatively homogeneous compared to data from other site media.

4.6 Occurrence of Organic Constituents of Concern and Cyanide

While much of Section 4 is devoted to a discussion of the role of metals occurrence, fate, and transport, the observation of numerous organic constituents in the historical characterization data warrants consideration in the RI characterization. Figures 12a through 12d present a summary of the distribution of analytical suites in historical sampling. Analyses for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs), pesticides, and cyanide are shown. In addition, the figures show the results of data screening using the same criteria and screening scenarios used for the metals discussion in Section 4.3. In cases where an analytical result exceeded one or more screening criteria, the figures show the results with the parameter, observed concentration, and screening value.

The results of this presentation are as follows:

- Historical solid-matrix sampling (Figure 12a) included a full suite of analyses in eight OU1 samples as a result of IEPA sampling. In addition, cyanide was included with metals analyses in several locations, and VOC and SVOC analyses were performed in the vicinity of the area of BTEX detections in groundwater at monitoring well G-04. Results included one detection each of hexachlorobenzene, benzo(a)pyrene, two PCBs, and three pesticides; each detection exceeded one or more criteria.
- Historical groundwater sampling (Figure 12b) included a full suite of analyses in five monitoring wells, non-contact cooling water, and the NPDES outfall. As

with the soil sampling, additional samples were collected for VOCs and SVOCs in the vicinity of the BTEX detections, and cyanide samples were collected in several locations with metals. Exceedances were limited to BTEX and naphthalene in one location, monitoring well G-04.

- Historical sediment sampling (Figure 12c) entailed a full suite of analyses in ten locations, with limited additional sampling for VOCs and SVOCs. One IEPA SSI location (SSI-206) at the northwestern corner of the holding pond exhibited ecological standard exceedances for several PAHs and cyanide. Additionally, several samples in the river upstream of the slag pile and Carus main plant area exhibited exceedances of screening values for PAHs, pesticides, and cyanide.
- Historical surface-water sampling (Figure 12d) only entailed analyses for cyanide in addition to metals. Of the three locations, the two upstream locations (one upstream of the M&H Zinc Company Site altogether and one near the upstream extent of the slag pile) had cyanide concentrations exceeding the ecological screening values.

In summary, historical characterization in all media included a limited number of samples for which “full-scan” analyticals (VOCs, SVOCs, pesticides, PCBs, and cyanide) were performed. In general, the data suggest that ancillary, non-metallic constituents are present only in isolated areas in concentrations that exceed human health or ecological screening values. No widespread trends of contamination are observed. The only case of constituents of interest concerns pesticides in northerly reaches of the river.

While widespread evidence of impacts has not been observed, the data do suggest the potential for limited impacts from ancillary constituents, including BTEX compounds, PAHs, PCBs, pesticides, and cyanide. Given site-specific circumstances, most notably the presence of former coal mine shafts, as well as the more general tendency for isolated pesticide and PCB presence at industrial sites, these limited impacts may be expected.

4.7 Potential for Asbestos Presence

The plant buildings for the Carus facility on OU1 operate under a detailed asbestos abatement and management program according to the internal Carus plan “Operations and Maintenance Program for Asbestos Containing Materials at Carus Corporation” (undated). However, historical records and visual reconnaissance of the remains of plant buildings in OU2 show widespread use of asbestos in building materials, including transite roof materials, fireproofing, etc. Hence, there is a potential for historical airborne deposition of asbestos fibers in OU1 resulting from the demolition of OU2 buildings at the conclusion of M&H Zinc Company manufacturing operations. Because the slag pile is the closest portion of OU1 to the core manufacturing areas of OU2, the slag pile is the most likely area to contain asbestos fibers deposited by air. Assuming that buildings were not demolished until after zinc production stopped, the deposited asbestos fibers might be present in the shallow surficial material of the slag pile as opposed to deeper horizons.

4.8 Conceptual Model Summary

While the TLR and its summary in Section 3 comprehensively present historic site analytical data with a relatively basic data screening, the purpose of Section 4 is to provide a more thorough analysis of existing data. This is performed by articulating the physical CSM, screening the data with a more detailed consideration of relevant OU1 media from the CSM, and using the results of this analysis to focus the attention on the most important constituents of concern, all of which are metals. A detailed discussion of the role of geochemistry in metals transport and bioavailability follows; this discussion focuses on the highest priority metals for OU1. Lastly, the status of non-metallic constituents in OU1 media is discussed.

The central conceptual elements to carry forward into the RI/FS are the following:

- While the upland process areas are impacted by a range of COPCs in isolated areas, the slag pile is the most important area of concern for OU1. As such, upland and upgradient site media, such as fill, till, gravel, and shale, are not expected to be impacted by the slag pile.

- By comparing analytical data from upgradient site media to those of the slag pile, a preliminary background assessment can be performed to identify the metals that most clearly stem from the slag. This is useful to develop an overall assignment of priorities for metals observed on OU1.
- The overall list of highest priority metals for the Site, in decreasing order, is as follows: zinc, lead, mercury, arsenic, cadmium, nickel, chromium, copper, manganese, silver, antimony, beryllium, iron, selenium, and thallium. This priority list is developed to focus upcoming effort on refined methods of analysis, including geochemical modeling and research into toxicology data; however, the risk assessment will consider all metals equally.
- The mechanisms that control the fate, transport, and bioavailability of metals are complex due to the degree of speciation possible. Metals behavior depends upon a broad range of geochemical variables. However, for the priority metals at OU1, some general trends are evident. Most importantly, acidic conditions in groundwater, which have been observed in the northern portion of the slag pile, will mobilize the majority of the priority metals. The effect of oxidation-reduction potential is more muted and tends to present a “trade-off” between the mobilization of one metal and the attenuation of a different metal. In addition, the highest priority metals are relatively insensitive to ORP.
- pH and ORP in OU1 groundwater are generally moderate, with the aforementioned exception of an acidic zone at the northern end. Elevated metals concentrations at one well in this area appear to confirm the conceptual understanding of the effects of pH on metals behavior.
- Full Target Compound List/Target Analyte List (TCL/TAL) characterization has been performed in limited locations in most media. No widespread impacts of organic constituents or cyanide have been observed, with the exception of pesticide detections in the Little Vermilion River. Isolated impacts from a broad range of ancillary COPCs, including BTEX constituents, PAHs, PCBs, pesticides, and cyanide are evident. These limited impacts are to be expected given the industrial history of the Site.

- Conceptual pathways for contaminant transport have been identified from OU2 that may impact site media in the Little Vermilion River, including the potential for sewer discharges to the river and overland flow to the river. The detection of pesticides in several locations in the river suggests that overland flow may play an important role.
- While the physical nature (e.g., lithology) of site media in OU1 was well characterized in historical investigations, recent site reconnaissance has indicated that there is potential for a strip of overbank deposits between the slag pile and the river to serve as a geochemical transition zone.
- Physical transport mechanisms are also conceptual pathways for contaminant transport. These include erosion of slag into the Little Vermilion River and transport downstream, as well as transport of potentially contaminated sediments that may have been impacted from the M&H Zinc Company Site.
- Overland flow is an additional physical transport mechanism of concern at the site. Surface runoff water can pick up soil (or slag) particles and transport these in overland flow for deposition at a lower land elevation or deliver sediment to receiving waters, such as the Little Vermilion River. Surface runoff water can also pick up dissolved parameters from contaminated soils and deliver impacted water to receiving waters as a nonpoint source of pollution.
- The presence of asbestos in site media may be of concern as many of the historic buildings, especially in OU2, have been demolished. These buildings likely contained asbestos-containing materials.

5. RI/FS OVERALL GOALS AND REQUIREMENTS

5.1 Introduction to Objectives

The RI/FS process will be conducted to select the necessity of and best strategy for the “adequate protection of human health and the environment” (USEPA, 1988, p. C-6). One of the first steps required in this process is the development of Remedial Action Objectives (RAOs), which constitute a broad assessment of potential receptors to be protected from potential exposures. To formulate this statement prior to commencement of RI/FS work, the following components must be understood:

- COPCs, not as formally identified in a risk assessment process, but instead, more fundamentally, as generally understood to constitute potential releases on or from the Site in sufficient concentration and known to cause adverse health effects in humans or ecosystems;
- pathways of concern (e.g., dermal exposure to slag, ecological exposure to impacted river sediments, etc.); and
- receptors of concern, including humans and ecosystems.

In essence, this is equivalent to the articulation of source-pathway-receptor scenarios of potential concern, the starting point for any formal risk assessment. This analysis has been performed and is reported in the risk assessment plans in Section 7 of this work plan.

A refinement of RAOs involves the designation of PRGs³, or quantitative thresholds or ranges of exposure for a given receptor to a given chemical. This step occurs after a significant degree of site characterization has occurred and screening has identified COPCs. PRGs are identified to address two needs:

³ In this instance, the term “PRG” is used in the general sense, as opposed to the specific sense associated with USEPA Region 9 PRGs for risk screening.

- **Risk Management:** In this approach, accepted quantitative measures of acceptable chemical loading to a receptor are used. These can be expressed as reference doses (RfDs) for non-carcinogenic effects or as slope factors (SFs) for carcinogenic effects. These benchmark values are an integral part of risk assessment; and
- **Statutory Requirements:** Separate from risk-based requirements, these stem from Applicable or Relevant and Appropriate Requirements (ARARs) and Information To Be Considered (TBCs). Maximum Contaminant Levels (MCLs) and occupational exposure limits from the Occupational Safety and Health Administration (OSHA) are examples of statutory requirements. Further information regarding potential ARARs and TBCs is discussed in Section 5.3.

5.2 Necessary Components of the RI/FS

In order to achieve the stated objective of protectiveness, the following components must be completed:

- The respondent must evaluate the nature and extent of contamination by characterizing and delineating releases of contamination, even if they have migrated off the Site, by giving due consideration to relevant constituents (e.g., the analytical suites discussed in this Work Plan).
- It is necessary to identify, screen, and, as needed, test viable remedial technologies. As stated in the RI/FS guidance (USEPA, 1988), this identification must cover a reasonably broad range of alternatives, including no action, limited action (institutional control), innovative, low-impact remediation (e.g., *in situ* groundwater remediation), and more aggressive physical approaches (e.g., capping).
- Formal risk assessments must be performed for both human health and ecosystem considerations. The risk assessments must address chronological phases (e.g., baseline and post-RI/FS remedy implementation).

- The FS must conclude with a recommendation for the best final remedial strategy to address the entire Site.

5.3 Evaluation of Potential ARARs

This section addresses the potential ARARs that may be encountered as part of implementation of this RI/FS, and ultimately the final remedy for this site. ARAR identification is an integral part of the site investigation and remediation process, as mandated under Section 121(d) of the CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA). ARARs are used to develop remedial action objectives, select the appropriate endpoints of site remediation, and govern implementation and operation of the selected remedy. In order to be classified as an ARAR, the National Contingency Plan (NCP) states that federal and/or state laws must meet one of the following two requirements: (i) applicability; or (ii) relevance and appropriateness. “Applicable” requirements are:

Cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. [40 CFR 300.5]

“Relevant and appropriate” requirements are:

Cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. [40 CFR 300.5]

In addition, the NCP identifies a third category of guidance, termed “information to-be-considered”. TBCs are guidelines or advisories that are issued by the federal or state government, but which are neither legally binding nor promulgated. However, these

guidelines may be used when they are necessary to ensure protection of public health and the environment (USEPA, 1991). If ARARs do not address a particular circumstance at a CERCLA site, then TBCs can be used to establish remedial guidelines or targets. Even when TBCs are used, the requirements imposed on the remedy, including cost-effectiveness, still apply (55 CFR 8745, 8 March 1990).

There are three broad categories of ARARs, as follows:

- chemical-specific ARARs are health- or risk-based concentrations that have been established for specific chemicals (e.g., related to hazardous substances present at the site);
- location-specific ARARs are restrictions on the concentrations of certain chemicals based on their specific physical locations at the site (e.g., related to site characteristics and site location); and
- action-specific ARARs are technology- or activity-based requirements on actions taken with respect to cleanup of hazardous substances at a site. These requirements are triggered by the particular activities that are selected to accomplish a remedy.

These categories are not always mutually exclusive and there may be some conceptual overlapping.

Table 5 displays a preliminary list of potential ARARs and TBCs. The table includes both federal and state requirements divided into those that address certain chemicals, locations, and actions. This list will be refined as needed during the course of remedy evaluation in the RI/FS.

6. CURRENT DATA NEEDS

6.1 Introduction

The TLR concludes with an identification of data gaps. This section discusses the data needs in greater detail based upon the TLR, as well as the additional analysis presented in Section 4. Data collected during the RI/FS will serve four major needs: (i) physical characterization of site media (e.g., subsurface lithology and waste extents); (ii) characterization of the nature and extent of contamination; (iii) refinement of understanding of chemical fate and transport and risk mechanisms; and (iv) data to support remedy evaluation. Data needs for these four major areas will be discussed individually. Note that while Section 7 will discuss in detail the proposed scope of work, Section 6.4 will include a detailed discussion of specialty analytical methods that will apply to the scope in Section 7.

6.2 Physical Characterization Needs

Physical characterization is necessary to understand site media or submedia that are likely to serve either as sources or pathways in complete source-pathway-receptor scenarios. The two most important site submedia in this regard are the slag and its underlying alluvium. Obtaining a better understanding of the lateral and vertical extent of slag (in the upland area of OU1 and within the river) will assist in the modeling of leachability and transport scenarios, as well as the development of conceptual exposure areas for human health risk assessment. Quantifying the thickness of the alluvium underneath the slag pile will assist with the quantification of potential mass loading in a downgradient transport scenario. Finally, physical characterization of slag depositional areas within the Little Vermilion River is also important in assessing potential sources.

6.3 Nature and Extent of Contamination

While the historical dataset provides a considerable level of understanding of constituent impacts to site media, several gaps in the extent of characterization have been identified. These data needs include the following:

- The metals analyte list employed throughout the past characterization programs was not always as comprehensive as now required. Specifically, 1994 investigation analyses tended to limit the metals analyses to the highest priority metals. As a result, much of the solid-matrix and groundwater datasets for the slag and underlying alluvium include a limited analytical list. With the added consideration of ecological screening values as part of the CERCLA process, a broader consideration of metals is necessary. Hence, it is recommended that additional data be collected that employs a full TAL list.
- As discussed in Section 4.6, a number of detections of ancillary constituents (PAHs, PCBs, pesticides, etc.) exceeded applicable screening values. It is recommended that further site characterization include these ancillary analytical groups in a percentage of samples. As indicated earlier, widespread areas of contamination are not anticipated; however, the historic data suggest that an expanded survey is appropriate. The one area where a more focused investigation of non-metallic COPCs is warranted concerns pesticides in the northern reaches of the river.
- Additional groundwater monitoring locations are recommended. The CSM of groundwater fate and transport as presented in Section 4 discusses several potential pathways of groundwater flow; of these, the most significant are (i) southward flow in the alluvium underneath the slag (of human health concern), and (ii) eastward discharge of groundwater from the slag into the river (primarily of ecological concern.) Hence, a refined understanding of groundwater conditions in the slag and in the underlying Holocene alluvium is warranted. At the same time, improving the understanding of groundwater conditions in other site media, including Pennsylvanian bedrock, Pleistocene till, and fill, particularly in background locations, will improve the understanding of background conditions as well as the overall hydraulic flow system.
- Updated, summary groundwater characterization and potentiometric mapping is recommended to obtain a “current baseline” of data. Given the sensitivity of metals concentrations to well condition and sampling method, the condition of groundwater monitoring wells should be evaluated, with redevelopment or

replacement a consideration in each case. In particular, it is recommended that the area of historical BTEX impacts (monitoring well G-04) undergo confirmation.

- Past characterization of shallow (0 to 5 ft BLS) soils was focused on certain areas of potential concern within the Carus main plant area. Additional sampling locations are warranted to collect subsurface data and to achieve a more even spatial distribution.
- An updated and more densely spaced series of sediment and surface-water samples, using broad analytical suites, is warranted for the Little Vermilion River to understand potential impacts from the M&H Zinc Company Site. Evaluation of overland flow is also warranted during the RI. As part of the overland flow evaluation, surface-water and sediment samples may also be collected, using a broad analytical suite for sample analysis.
- As discussed in Section 4, there is a potential for the presence of asbestos fibers in soil. A review of guidance provided by the Colorado Department of Public Health indicates that the status of risk assessment related to asbestos in soil is evolving; however, it appears that disturbing soil (or slag in this case) and collecting ambient air samples for particles is the most rigorous approach. Hence, as part of the physical characterization of slag in the upland area (Section 6.2), it is recommended that ambient air sampling be performed in slag locations closest to OU2.

6.4 Fate, Transport, and Risk Mechanisms

6.4.1 Rationale

As discussed in Section 4, developing a detailed understanding of the geochemistry of site media is a critical component of a thorough RI/FS for a metals-dominated project such as the M&H Zinc Company Site. The individual metal summaries provided in Section 4.4.1 indicate that the 15 priority metals can exist in a significant variety of species with widely varying mobility, bioavailability, and stability. While conventional,

total metals concentrations are often adequate for risk assessment, obtaining a more detailed understanding of metals speciation through specialty analyses will provide one or more of the following benefits:

- Certain specialty analyses, such as Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM) analyses, are necessary to accurately quantify the true ecological risk because they indicate the fraction of metals concentrations that are not bioavailable even if present in site media. As such, they serve as an extension of the characterization of the nature and extent of contamination.
- Other analyses clarify the mechanisms by which metals sorb to site media, which will considerably improve the conceptual model of attenuation, if it is occurring. By understanding the attenuation mechanisms, it may be possible to more precisely and accurately predict future concentrations, which will assist in risk-based decision making and identification of remedial options.
- Various potential remedies may affect site geochemical conditions in a variety of ways. Because the mobility of the metals on the Site is controlled by the geochemical conditions, gaining a better understanding of the speciation of metals at the Site will allow for a better understanding of the impacts that various remedies may have on metals mobility.

6.4.2 Description of Specialty Analyses

6.4.2.1 Acid Volatile Sulfide/Simultaneously Extracted Metals

This specialty analysis for sediment is used to measure the bioavailability of five metals (cadmium, copper, lead, nickel, and zinc), all of which are priority metals for OU1. These metals are commonly present as sulfides in sediment under reducing conditions. The sulfide fraction has limited mobility and low toxicity to benthic and aquatic organisms. Hence, free sulfide in sediment serves as an effective “metals sink”; moreover, the divalent state of the five metals indicates that from a molar standpoint, the metals are interchangeable. For this reason, the AVS/SEM analysis includes two parallel analyses: (i) quantification of AVS in sediment; and (ii) quantification of total

metals concentrations for the five metals. Both results are expressed in units of mmol, which allows a direct comparison. If the AVS is equal to or higher than the SEM result, it provides strong evidence of the inertness of the metals provided that reducing conditions are maintained.

6.4.2.2 Sequential Extraction Procedure

Sequential Extraction Procedure (SEP) analyses are primarily focused towards a detailed evaluation of metals speciation, although they can be used for bioavailability assessments. SEP consists of six different extractions of metals from a soil or sediment sample. Each extractant is intended to liberate metals bound by a particular sorption mechanism; in general, the extractions become increasingly aggressive. After the full sequence, it is possible to estimate the relative importance of sorption mechanisms by comparing the relative recoveries of the six extraction steps. By understanding which of the six possible sorption mechanisms are currently occurring, one can dramatically improve the understanding of attenuation processes, seek *in situ* remedial options, and predict the unintended geochemical effects of a given remedial action.

The extraction steps are as follows:

Step 1 - Exchangeable Phase: This extraction captures metals that are reversibly sorbed to soil minerals, amorphous solids, and/or organic material by electrostatic forces. A significant fraction of a given metal in this state is of concern, because this sorption mechanism is weak; the sorbed metal can be easily replaced (i.e., returned to solution in groundwater) by other, less toxic cations or anions. Metals in the exchangeable phase are considered easily bioavailable. The test involves exposing the soil to a concentrated electrolyte solution, such as 1 molar (M) magnesium sulfate, that displaces the trace elements from solid surfaces.

Step 2 - Carbonate Phase: This extraction targets trace elements that are sorbed or otherwise bound to carbonate minerals. Carbonate minerals are more stable than electrostatically-driven sorption; the carbonate fraction is considered potentially bioavailable. The test involves extraction with a mild acid solution (1M sodium acetate solution in 25% acetic acid at pH 5). By lowering the pH from neutral conditions to 5,

bicarbonates will be converted to carbonic acid, thereby liberating bicarbonate-bound metals.

Step 3 - Metal Hydroxide Phase: Trace elements commonly bind to hydroxides of iron, manganese, and aluminum; this is an important attenuation process. In this extraction step, metals are extracted using a solution of 1M hydroxylamine hydrochloride in 25% v/v acetic acid. This is a strongly reducing step that converts iron(III) to iron (II), among other changes. This step is important, because it will predict the changes (i.e., increased metals mobilization) that may occur if a remedy is selected that reduces recharge and, in turn, oxygenation to metals source areas.

Step 4 - Organic Phase: This extraction step targets trace elements strongly bound via chemisorption to organic material. Oxidation of soil organic matter (using an extractant at pH 9.5; at 5% sodium hypochlorite), will bring into solution metals bound to organic functional groups.

Step 5 - Acid/Sulfide Fraction: The extraction is used to identify trace elements precipitated as sulfide minerals. Metals associated with sulfide minerals will be extracted by leaching the soils with a 3:1:2 v/v solution of hydrochloric acid, nitric acid, and water to dissolve the metal sulfide minerals. Like Step 4, this is an oxidative step; however, this step occurs at low pH.

Step 6 - Residual Fraction: Trace elements remaining in the soil after the previous extractions will be distributed between silicates, phosphates, and refractory oxides. These residual metals can be removed from the soil through total dissolution with hydrofluoric acid, nitric acid, hydrochloric acid, and boric acid. This is an unusually aggressive step that goes beyond the degree of extraction from conventional total metals analyses; this step actually degrades soil minerals.

As a general rule, all metals fractions that are not extracted until Step 3 or later are considered non-bioavailable.

6.4.2.3 Other Specialty Methods

Several other specialty analytical methods are desirable for conceptual model development. Most of these methods are more common than AVS-SEM or SEP and tend to provide qualitative instead of semi-quantitative results; however, they can be used in combination as individual lines of evidence to improve the understanding of metals attenuation processes. These methods are as follow:

Synthetic Precipitation Leaching Procedure (SPLP): This method is similar to the TCLP method used in historical work; however, it is designed to use ambient pH instead of the more acidic pH selected under TCLP to mimic landfill leachate. It can provide a general understanding of leachability potential for solid samples.

Soil pH: As noted earlier, this is a “master variable” that has far-reaching effects on metals speciation.

Field parameters from groundwater sampling (pH, ORP, dissolved oxygen (DO), conductivity, temperature, and turbidity): These parameters, while routine from the standpoint of sampling, play a critical role in data evaluation for metals characterization. pH and ORP, with DO as an indicator related to ORP, are the “master variables” for metals speciation. Elevated turbidity may serve as an explanation for unusually high metals results. All parameters are used to evaluate purge stabilization.

Ferrous iron, total organic carbon (TOC), orthophosphate, sulfate, sulfide, and alkalinity: Some of these parameters serve as corroborating evidence for pH and ORP values measured in the field; alkalinity will confirm pH understanding, whereas sulfate, sulfide, and ferrous iron will refine the understanding of the oxidation-reduction conditions. Most of these parameters will also be useful inputs to geochemical models, if desired. Lastly, some of these parameters, such as ferrous iron, will indicate the degree of iron sorption sites, which are valence state-dependent.

X-Ray Diffraction (XRD): This analysis will characterize the mineral composition of the soil, which directly affects the sorptive capacity of soils.

6.4.2.4 Other Risk Assessment-Related Data

Certain OU1 reconnaissance activities are necessary for the development of the ecological risk assessment. The two most important activities will include: (i) a reconnaissance of sediment deposition patterns in the river to refine sediment sampling locations; and (ii) a habitat survey, addressing terrestrial, riparian, and aquatic systems to refine the selection of receptors for the risk assessment.

6.5 Remedy Evaluation Data

As discussed in Section 6.4, much of the specialty analytical work to explore metals geochemistry will support an evaluation of remedial alternatives. Additional activities geared specifically for remedy evaluation, such as geotechnical borings to evaluate slag pile stability, are likely to be performed during the FS.

7. REMEDIAL INVESTIGATION SCOPE OF WORK

7.1 Introduction

Section 6 provides a discussion of the data gaps identified as part of the Work Plan preparation process. It also discusses the rationale and methods underlying specialty analyses that will be used to better understand metals geochemistry. Section 7 presents the detailed scope of work as follows:

- Section 7.2 describes the solid matrix sampling program;
- Section 7.3 describes the surface-water and sediment characterization program;
- Section 7.4 describes the groundwater characterization program; and
- Section 7.5 presents the ecological habitat characterization program.

For the programs discussed in Sections 7.2 through 7.5, the reviewer is referred to the FSP, QAPP, and HASP for specific protocols for field sampling and laboratory analyses. Table 6 of this document provides a summary of sampling locations and planned analytical suites for the solid matrix, river, and groundwater samples.

Sections 7.6 and 7.7 provide risk assessment approaches for human health and ecological receptors, respectively. Section 7.8 presents the surface-water basin analysis to evaluate overland flow, and Section 7.9 discusses the RI Report.

Since data validation was performed for investigations in Geosyntec's major historical investigations (the 1993 and 1994 investigations), the historical data will be added to the site database for use in risk assessment. The characterization plan presented herein has been designed in consideration of historical data.

7.2 Solid Matrix Characterization Program

This section of the scope of work is referred to as "solid matrix" sampling instead of "soil" sampling, because it will include both waste material (e.g., slag) and true soil. Figure 13a presents an overview of the solid matrix sampling program. The program

addresses two major sampling areas: (i) the slag pile (SB-301 through SB-310); and (ii) the Carus main plant area (SB-311 through SB-319). The number of locations selected was based on appropriate sampling quantities to support human health and ecological risk assessment. The programs for the two areas can be summarized as follows:

- The slag pile program consists of ten borings with sampling intervals on multiple horizons. Each boring will include samples collected from: (i) 0 to 1 ft BLS to characterize direct contact risks; (ii) 5 ft above the water table; and (iii) 5 ft below the water table (see exceptions identified in Section 2.2.2 of the FSP). Two borings will also include a fourth sample collected from alluvium underneath the slag. Additional sampling horizons were deemed unnecessary in light of the vertical homogeneity of slag concentrations observed during sampling performed in conjunction with the 1994 investigation, as discussed in Section 4.5 of the Work Plan. The analytical program will consist of the following:
 - TAL metals for all samples;
 - VOC, SVOC, and cyanide analyses for approximately 25% of samples;
 - pesticides and PCBs for 0-1 ft samples in alternating borings;
 - asbestos measured in air samples collected at three locations during trenching operations conducted on the northern portion of the slag pile as part of the solid matrix characterization program;
 - TAL SPLP and soil pH in approximately 33% of samples;
 - SEP analyses in five samples; and
 - XRD analyses in three samples.

The slag characterization program will also address the physical characterization requirements discussed in Section 6. The drilling rig will drill to the top of bedrock surface when sampling alluvium in two locations to provide an estimate

of alluvial thickness. Also, the areal extent of slag will be delineated using either a drill rig or backhoe for test trenching. Boundary points for the southern, western, and northern boundaries will be selected on 150 ft centers.

- The Carus main plant area program consists of nine locations with two samples each at 0 to 1 ft and 2 to 4 ft BLS to support risk assessment. While only a long term commercial/industrial scenario will be considered for the main plant risk assessment, characterizing the surficial and subsurface zones will allow a differentiation of risks between general site use (for which shallow data are relevant) and construction worker activities (which involve deep soils). This may be of value in remedy determination, because if the deeper horizon exhibits higher risks than those of the shallow horizon, it may be possible to impose land disturbance restrictions as a remedy component. The analytical program will include the following:
 - TAL metals for all samples;
 - VOC, SVOC, and cyanide analyses for approximately 25% of samples;
 - pesticides and PCBs in 25% of samples;
 - SEP analyses in four samples; and
 - XRD analyses in three samples.

Table 6 provides a detailed record of the proposed analyses for each sample. The SPLP and pH analyses are employed in the slag pile due to the anticipated potential for leachability; they are omitted from the main plant area program because of lower chemical concentrations measured during past investigations. However, the XRD and SEP analyses are tested in both areas, because both areas will require consideration of bioavailability based on concentrations elevated above screening values.

7.3 Surface-Water and Sediment Characterization Program

The surface water and sediment characterization program addresses two areas of the site: (i) the Little Vermilion River; and (ii) the upland area of OU1.

7.3.1 River Characterization Program

The Little Vermilion River Characterization Program will be conducted in a phased manner. The first phase consists of two primary components: (i) physical characterization; and (ii) analytical evaluation of sediments and surface water. Based on the first phase, additional sediment and surface-water samples may be required. Sufficient phases will be conducted and data will be collected to characterize the nature and extent of contamination within the Little Vermilion River due to the M&H Zinc Company Site.

The objective of the physical characterization program is to collect information that will allow mapping of the Little Vermilion River from the Quarry bridge to the Illinois River with respect to sediment and slag depositional areas. The Little Vermilion River will be traversed by foot or non-motorized vessel (e.g., kayak, canoe, or raft) from the Quarry bridge to the Illinois River (approximately 13,000 ft in length). Visual observations will be noted along the length of inquiry to map both sediment and slag depositional areas. Three levels of slag physical characterization will be conducted: (i) the location of slag boulders (greater than 1 ft in diameter) will be surveyed using hand-held global positioning system (GPS) equipment; (ii) depositional areas where slag gravel and cobbles are present in sizes ranging from about 1/2 inch to 12 inches in diameter will be mapped (these areas will be investigated using shovels and/or grab sampling equipment designed for this type of sampling); and (iii) approximately 20 grab samples will be collected along the river (based on sediment depositional areas) to quantify the slag mass fraction using sieves and scales.

The objective of the analytical program is to collect sediment and surface-water samples to evaluate potential impacts due to the Site. Samples will be collected from the river along the M&H Zinc Company Site, as these samples are anticipated to be most heavily impacted by the site as compared to samples further downstream. One of these samples

will be collected from the sediment depositional area just north of the dam, which is associated with OU2. Upstream samples will also be collected to establish background. In total, 14 sampling stations will be spaced approximately 600 to 700 ft apart on the river (Figure 13b). The exact sampling locations will be contingent on the presence of sediment (as sediment depositional areas are sporadic in this reach of the river). Two of the locations are upstream and are located in close proximity to historically sampled upstream locations. Co-located sediment and surface-water samples will be collected from half of the locations along the Site proper. Sediment samples only will be collected from the remaining river characterization locations. The surface-water and sediment data will be used as input for the Screening Level Ecological Risk Assessment (SLERA) and the Human Health Risk Assessment (HHRA).

The analytical program will consist of the following:

- TAL metals in all samples;
- VOCs, SVOCs, PCBs, and pesticides and cyanide in 25% of samples along the Site proper and in both upstream locations;
- additional pesticide characterization in all locations near the group of historical pesticide exceedances (LVR-206, LVR -207, and LVR -208); and
- AVS/SEM in four locations along the Site proper.

Three staff gauges will be installed and surveyed in the bank of the river at roughly equidistant locations to allow a comparison of river stage values with potentiometric data from monitoring wells. Due to the rugged terrain of the riverbank, precise locations of the staff gauges will be determined based on ease of installation.

7.3.2 Upland Characterization Program

If surface water is present during the RI, one co-located surface water and sediment sample will be collected from an area to the west of the abandoned ICRR grade (now dirt road) just north of the gate located north of the emergency bypass pond. At this location, on 1 May 2007, a seep was observed emanating from the sinter pile (also

referred to the ash disposal area on historic M&H Zinc Company maps). The water seeping out of the sinter was observed to accumulate along both sides of the dirt road with no apparent surface-water flow pathway.

Carus will also observe the OU1 site immediately following a significant rain event to look for additional areas where surface water flow is present. If noted, up to three co-located surface water and sediment samples will be collected. Areas to be considered will be based on the surface-water basin analysis discussed in Section 7.8 of the Work Plan.

The analytical program will consist of TAL metals, VOCs, SVOCs, PCBs, pesticides, and cyanide in all samples.

7.4 Groundwater Characterization Program

7.4.1 Introduction

As described in Section 2, the OU1 groundwater flow system consists of several matrices with highly dissimilar characteristics, including Pennsylvanian bedrock, Pleistocene till, Holocene alluvium, fill, and slag. The data needs discussion in Section 6 indicates the importance of two specific potential flow pathways (southward flow in the alluvium and eastward discharge of groundwater from the slag into the river) as well as an understanding of groundwater quality in all media.

In general terms, the goals of the groundwater characterization program can be summarized as follows:

- perform sufficient groundwater characterization in the two most significant transport media, slag and alluvium;
- develop a sufficient understanding of background conditions, which primarily correspond to bedrock groundwater;
- conduct a limited characterization of other media, including fill and Pleistocene till;

- evaluate vertical gradients among media;
- perform an analytical sampling program that addresses all analytical parameters while focusing on those of greatest significance, i.e., metals;
- collect groundwater samples of consistent quality to avoid unnecessary variability in sample turbidity or well productivity;
- incorporate groundwater quality data generated in OU2; and
- perform representative hydraulic characterization of sampling media.

Hence, the groundwater characterization scope will consist of the following components: (i) reconnaissance and rehabilitation of the existing well network, (ii) installation of additional monitoring wells, (iii) sampling of the expanded well network for a broad suite of analyticals, (iv) potentiometric mapping, including an evaluation of vertical gradients, and (v) hydraulic characterization. There will be close coordination with SulTRAC on matters pertaining to potentiometric gauging and well survey to ensure that a coherent, sitewide dataset is obtained. In addition, to the extent practicable, Geosyntec will coordinate with SulTRAC to coordinate the groundwater sampling event in an attempt to ensure consistent groundwater sampling protocols.

7.4.2 Well Reconnaissance and Rehabilitation

As discussed with USEPA and SulTRAC, a monitoring well network reconnaissance will be performed to evaluate the condition of all monitoring wells prior to sampling. Since no wells have been developed in the last five years, all wells will be redeveloped at a minimum, and replaced as needed, if turbidity cannot be stabilized per the FSP. Controlling turbidity is particularly important for OU1 due to the demonstrated effect of turbidity on metals concentrations. The integrity of the well cap, pad, and locking system will also be evaluated.

7.4.3 Well Network Expansion

The current network of 18 monitoring wells consists of five wells each in bedrock and slag, three wells each in alluvium and till, and two wells in fill. To meet the objectives of a representative sampling of different site media, with a focus on site media of greatest transport significance, five new monitoring wells in slag, four new monitoring wells in the alluvium, and three new monitoring wells in the bedrock will be installed. This will complete a network of 30 wells, consisting of ten wells in slag, eight wells in bedrock, seven wells in alluvium, three wells in till, and two wells in fill. Figure 13c shows the locations of the 12 new wells, which have been selected to meet several objectives, including a relatively even spatial distribution for wells in a given medium, co-location of wells in differing media to evaluate vertical gradients, and co-location with boring locations from the solid matrix characterization program (Section 7.2) to optimize drilling effort.

7.4.4 Monitoring Well Sampling

Upon the installation and development of new wells, the analytical program for groundwater will include the following analyses in the proportions given:

- TAL metals in all samples;
- VOCs, SVOCs, and cyanide in 25% of samples;
- field parameters (including ferrous iron, sulfide, and alkalinity) in all samples; and
- TOC, orthophosphate, and sulfate in two background locations and two groundwater samples collected from wells screened within each submedium (e.g., slag, alluvium, fill, etc.).

7.4.5 Potentiometric Gauging

A synoptic round of sitewide water levels will be collected on a quarterly basis for four consecutive quarters to evaluate seasonal variability. All water levels will be collected

on the same day and compared to readings from staff gauges installed in the Little Vermilion River as described in Section 7.3. The water levels will allow an evaluation of horizontal and vertical gradients.

7.4.6 Hydraulic Characterization

Of the 18 existing monitoring wells, 11 have undergone hydraulic testing via slug or pump testing; these include four bedrock wells, one slag well, three alluvial wells, two till wells, and one fill well. Of the new monitoring wells, four slag wells will undergo slug testing. This will ensure that at least half of the monitoring wells from each medium will have associated hydraulic conductivity data.

7.5 Ecological Habitat Characterization Program

The SLERA (described in greater detail in Section 7.7) will rely on an initial field component of habitat characterization. As an early step in screening-level problem formulation, fundamental knowledge of the potential environmental setting (representative habitats and wildlife) at a site must be documented. As such, the habitat characterization will be performed as a preliminary site ecological survey concurrent with the analytical characterization components of the work plan.

The goal of the habitat characterization is to identify and characterize the current and potential threats to the natural environment from hazardous substance release. Habitat characterization of OU1 will identify habitat types occurring on the site, probable pollutant transport routes, and possible indicator species or a species population to serve as the focus of the study, as warranted. Threats to the environment include not only existing adverse ecological impacts but also the risk of such impacts in the future.

Habitat characterization will consist of a review of available data and a site visit. Current information on ecological resources of the Site, including jurisdictional wetlands, sensitive habitats, and protected species will be sought from state and federal natural resource agencies, including the USGS, Illinois Natural Heritage Program, State Game and Fish Departments, and U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory. Information including topographic and recent aerial maps will be used in the canvassing of site habitat information. Following the review of current,

available information, personnel qualified in ecological assessment will conduct a site visit to identify and describe natural areas (e.g., upland forest, on-site stream, or nearby wildlife refuge) and disturbed/man-made areas (e.g., lagoons). Direct observations of dominant plants and wildlife (especially any occurrence of protected species), including animals signs in the form of middens, nest, tracks, burrows, droppings, calls, etc., will be documented in the site visit. The combination of desktop study and site visit will result in a habitat characterization providing a description of habitats present on site including those that may be potentially contaminated or otherwise disturbed.

This information will be used to assist in the refinement of assessment endpoints for the ecological risk assessment described in Section 7.7.

7.6 Human Health Risk Assessment

7.6.1 Introduction

This section describes the proposed approach to the HHRA for the Site. The purpose of the HHRA is to evaluate potential human exposures, such as contact with affected media (e.g., slag, sediments, groundwater, and soil) to site-related chemicals. The HHRA will evaluate potential adverse health effects that may result from exposure to COPCs in the absence of any remedial action. The risk assessment will adopt a conservative approach that relies upon upper bound exposure parameters to identify key chemicals of concern and exposure pathways. Additional focused risk assessment studies may be warranted depending on the results of the HHRA.

This Work Plan and the subsequent risk assessment will adhere to the Risk Assessment Guidance for Superfund (RAGS), Volume I - Human Health Evaluation Manual (USEPA, 1998) and appropriate State guidance. When available, the HHRA will consider site-specific information to characterize exposure conditions.

In accordance with USEPA guidance, the HHRA will consist of four components:

- identification of chemicals of potential concern;
- exposure assessment;

- toxicity assessment; and
- risk characterization.

Previous sections of this RI/FS Work Plan contained a detailed description of the physical characteristics of the Site, the nature and extent of the chemicals at the Site, and the land use in surrounding areas. This information was relied upon to develop the risk assessment approach.

Note that the ASAOC requires the completion of a comprehensive risk assessment for the entire M&H Zinc Company Site, which will include the coordination of risk assessment activities with SulTRAC, USEPA's contractor for the OU2 risk assessment. The risk assessment approaches for both OUs will embrace the same general principles of risk assessment development; however, as discussed with USEPA and SulTRAC, specific assumptions for the two OUs may vary in cases where differing site circumstances so warrant. For example, the residential portions of OU2 will naturally undergo risk screening using residential assumptions, whereas human health risk screening in the main plant and slag pile areas of OU1 will use industrial setting assumptions appropriate for the current and future exposure associated with ongoing manufacturing activity at the Carus facility.

7.6.2 Definition of Assessment Area

As required under the RI/FS ASAOC, this Work Plan and the subsequent HHRA will evaluate groundwater, soil, slag, the Little Vermilion River, and potential land uses and human exposure pathways within, and in the vicinity of, the site.

7.6.3 Evaluation of Data

As discussed in Section 3 of this Work Plan, multi-media investigations have been conducted in OU1 since 1991. The sampling of soil, slag, groundwater, and sediment during investigative activities conducted since 1991 has resulted in a considerable, multi-media database, of which the data for the major investigative components have undergone validation. This extensive database will be used to supplement the proposed characterization scope.

Whereas the typical grid approach to soil sampling gathers data with little regard to known releases or contamination, the extensive targeted sampling programs conducted at the Site have created a database that is relatively devoid of samples collected from unaffected areas and rich in samples collected from source areas. The focused nature of the database will result in a conservative estimate of potential risk.

7.6.4 Identification of COPCs

7.6.4.1 Overview

Comparisons of the analytical results for various media to USEPA Region 9 PRGs and IEPA Tiered Approach to Corrective Action Objectives (TACO) values will serve as the primary basis for identifying COPCs included in the quantitative risk estimation. This step allows for a more focused and detailed evaluation of potential risk associated with the most relevant chemicals by eliminating those chemicals detected at concentrations below conservative screening criteria.

7.6.4.2 Methodology

For those chemicals detected in soil samples, the maximum detected concentrations will be compared to soil screening criteria provided in current USEPA Region 9 screening values for an industrial worker scenario, as discussed with USEPA in a 2 May 2007 meeting. In addition, data will be screened against IEPA TACO Soil Remediation Objectives for Industrial/Commercial Properties. The industrial scenario is appropriate for OU1 due to the ongoing manufacturing activities at the Carus facility and the related access restrictions (e.g., fencing) to the slag pile. Site-wide groundwater samples will be compared to USEPA Region 9 groundwater quality criteria and TACO Tier 1 criteria for groundwater.

For those chemicals with a maximum detected concentration exceeding the relevant screening criteria, or without screening criteria, further consideration is given to the nature of the chemical, detection frequency, and the relative site-related background concentration. Chemicals will be eliminated from consideration as COPCs if the chemicals are classified as essential nutrients (e.g., calcium and magnesium) and occur at concentrations that would not produce exposures greater than the United States

Department of Agriculture (USDA) Recommended Daily Allowances (RDA) or Safe and Adequate Daily Intakes (SADI). Chemicals will also be eliminated if all of the following are true:

- the chemical was detected in only one out of ten or more samples in a given medium, or in approximately 5% or fewer out of 20 or more samples in a given medium and without any spatial correlation; and
- the chemical is not found in media indicating site-related transport.

Background conditions will be considered; this is an important step for metals data. Background considerations will proceed initially through a review of available literature sources, including IEPA sources and USGS reports. Data collected from the OU2 residential program will also be assessed. A background characterization study may be performed if sufficient data are unavailable.

After all the above criteria have been considered, chemicals remaining with either maximum detected concentrations greater than the screening criteria, or for which there are no screening criteria, will be identified as COPCs. As the ecological risk characterization utilizes differing screening criteria, separate sets of chemicals will be selected as COPCs for the HHRA and the ERA.

The HHRA will involve the characterization of potential human health risks for the COPCs identified for the Site using receptors and completed exposure pathways identified in the Human Health Conceptual Site Model (HHCSM). This risk assessment will incorporate the following elements: (i) exposure assessment; (ii) toxicity assessment; (iii) risk characterization; and (iv) uncertainty analysis. These elements will be completed in conformity with RAGS Part D and each element will become a major subsection of the HHRA report.

7.6.5 Exposure Assessment

This section of the risk assessment addresses the environmental fate and transport of the identified COPCs and the potential pathways by which human receptors could be exposed. This requires a description of the exposure setting in terms of the natural

environment and local land use and demographics. The purpose of this description is to provide the information needed to identify potential exposure pathways and receptors, and to estimate exposure factors (e.g., amount of soil ingested, amount of water consumed, etc.) for these receptors. Potential human exposure pathways will be identified in the context of the current and potential future land uses.

The exposure assessment is the process of establishing a quantitative estimate of the exposure for each receptor through each completed pathway. This process incorporates the exposure factors and exposure point concentrations (i.e., the concentration at which receptors are assumed to be exposed in site media) into standard USEPA risk equations (USEPA, 1989). The resulting calculations result in an estimate of the average daily dose (ADD) for non-carcinogens and the lifetime average daily dose (LADD) for potential carcinogens.

Exposure factors required for risk calculations will be selected based on the specific media and completed pathways identified in the HHCSM. For example, soil exposures may require estimates of soil ingestion, skin surface area exposed to dermal exposure, inhalation rates, exposure frequencies, and exposure durations. The specific values proposed for exposure factors will be developed in a site-specific manner to correspond to realistic activity patterns that could occur at the Site, where possible, rather than defaulting directly to USEPA's conservative default exposure scenarios. The primary source for exposure factor-related information will be the Exposure Factors Handbook (USEPA, 1997).

Two specific limitations in the exposure characterization discussed with USEPA in the 2 May 2007 meeting include the following:

- omitting a trespasser scenario from the Main Plant area due to the fencing and security of the active facility, and
- developing exposure parameters that correspond to infrequent workers in the slag pile area due to the limited use of this area by Carus employees.

Hence, scenarios for the HHRA will include the following:

- long-term commercial/industrial scenario in the main plant area;
- site-specific long term, maintenance/inspection worker scenario for the slag pile and;
- fisherman trespasser scenario for the Little Vermillion River.

A complete exposure pathway includes the following: (i) a chemical source and release mechanism; (ii) a medium for transport; (iii) an exposure point (i.e., where human contact with the contaminated medium occurs); and (iv) an intake route for the contaminant into the body at the exposure point. If any of these elements are missing, the pathway is incomplete and is not considered further in the risk assessment.

The 95 percent upper confidence limit (UCL) on the mean is the standard statistic recommended by USEPA as a conservative estimate of the average site exposure concentration (USEPA, 1989). High variability in the data can sometimes result in the calculation of a UCL on the mean that exceeds the actual maximum detected concentration. In such cases, the exposure point concentration will not exceed the actual maximum detection.

Exposure point concentrations based on 95 percent UCLs will be evaluated using EPA software developed specifically for this purpose (PROUCL, 2007). EPA approved techniques will be employed to calculate UCLs when data contain non-detected samples (i.e., those results with a “U” qualifier). Estimated concentrations (i.e., those results with a “J” qualifier) will be included as true detected values in the calculation of the 95 percent UCL on the mean and other qualifiers will be handled according to RAGS (USEPA, 1989). Upon establishment of the exposure factors and exposure point concentrations, receptor intake will be calculated as ADDs and LADDs for each completed pathway.

Depending upon a preliminary review of the spatial distribution of the data, Geosyntec may request that USEPA consider area-weighted averaging as a method of calculating a more realistic exposure-point concentration. Geosyntec and SulTRAC will coordinate efforts to ensure that such methods of calculation are performed only as part of a

consistent risk assessment framework across the M&H Zinc Company Site. Specifically, area-weighted averaging will be either (i) employed consistently or omitted altogether from the Site, or (ii) partially employed only if circumstances specific to the exposure units warrant differing treatment.

7.6.6 Toxicity Assessment

The toxicity assessment identifies estimates of the non-cancer toxicity and potential carcinogenicity (toxicity values) for each COPC suitable for use with the dose estimates calculated in the exposure assessment step. The primary source for toxicity values (reference doses for non-cancer effects and cancer potency factors for cancer effects) will be from the USEPA Integrated Risk Information System (IRIS). If IRIS data are unavailable, toxicity information will be developed using the following hierarchy: USEPA's Provisional Peer Reviewed Toxicity Values (PPRTVs); Health Effect Summary Tables (HEAST); or other State promulgated toxicity information (e.g., IEPA, Cal EPA). Risks will not be calculated for chemicals lacking an regulatory-accepted toxicity value. Adjusted SFs and RfDs for the dermal route of exposure are derived from the oral slope factors and RfDs using chemical specific oral absorption efficiencies.

7.6.7 Risk Characterization

Risk characterization utilizes the dose estimated in the exposure assessment coupled with the toxicity values identified in the toxicity assessment to calculate estimates of the potential non-cancer and excess cancer risk associated with site-related exposure to the COPCs. In addition to deriving these quantitative estimates, the risk characterization provides an interpretation of the potential significance of the risk estimates by comparing them to regulatory guidelines indicating the need for addressing potential risks.

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of pathway-specific exposure to carcinogenic chemicals. Cancer risk levels are related to USEPA's target range of 1×10^{-4} to 1×10^{-6} for incremental cancer risk. Cancer risk levels less than 1×10^{-6} are considered not

significant, and cancer risk levels greater than 1×10^{-6} require further characterization and discussion.

For non-carcinogens, risks will be evaluated by calculating the ratio of the average daily intake during the exposure period to the RfD. This ratio is the hazard quotient (HQ). For a given medium and target organ, HQs for each COPC are summed to obtain a Hazard Index (HI) for each target organ. A HI greater than one indicates that potential health effects associated with the exposure medium cannot be eliminated. Discussion of the HIs will be provided to characterize potential non-carcinogenic human health effects.

7.6.8 Uncertainty Analysis

A description of the significant sources of uncertainty and the anticipated extent of these uncertainties will be provided along with quantitative risk estimates to inform risk managers and decision makers of the confidence in the conclusions of the risk characterization. The Uncertainty Analysis will identify sources of uncertainty related to the analytical data, the characterization of exposures, and the toxicity values used. The implications for these uncertainties with regard to the conclusions of the risk assessment will be described.

There are multiple sources of uncertainty that may be identified for any risk characterization. The purpose of this section will be to provide a discussion of the significant sources of those uncertainties along with the quantitative risk estimates to inform risk managers and decision-makers of the confidence in the conclusions of the risk characterization. The uncertainty analysis will identify sources of uncertainty related to the analytical data, the characterization of exposures, and the toxicity values used.

7.6.9 Assessment of Asbestos Data for Ambient Air

The ambient air monitoring for asbestos as described in Sections 6.3 and 7.2 will employ National Institute for Occupational Safety and Health (NIOSH) Method 7400, Phase Contrast Microscopy (PCM). This method has the advantage of direct usability with respect to toxicological benchmarks available on USEPA's IRIS. This method is

also conservative in that it analyzes for particles of a size consistent with airborne asbestos fibers, but it does not indicate the asbestos loading per se. Hence, it is possible to overestimate the true asbestos concentration. The ambient air data collected will be compared to IRIS carcinogenic risk values and discussed with USEPA. If the potential for unacceptable risks cannot be eliminated, then additional analytical methods that more clearly identify asbestos will be employed in a subsequent sampling event.

7.7 Ecological Risk Assessment

7.7.1 Overview

Ecological risk assessment (ERA) will be conducted to support the RI/FS at the Site. The purpose of the ERA is to evaluate the nature and extent of potential ecological risks due to chemicals in the surface water, sediment, surface soil, and biota associated with the site.

Standard risk assessment practice is to employ a stepwise approach to evaluate chemical risks. The SLERA represents the initial step of the assessment at the Site. The SLERA will be performed in accordance with the USEPA's guidance for ERAs (USEPA, 1997, 1998).

As specified by the guidance, the initial assessment of ecological risk is conducted using rapid, simple approaches and conservative exposure assumptions to minimize the possibility of a false negative finding. In this way, those exposure pathways that clearly pose negligible risk are rapidly eliminated from further consideration, and those that are not eliminated are passed along to more detailed and progressively quantitative assessment tiers. The assessment paradigm employed in Superfund assessments consists of eight general steps as follows.

- Step 1 - Screening-Level Problem Formulation and Effects Evaluation;
- Step 2 - Screening-Level Exposure Estimate and Risk Calculation;
- Step 3 - Baseline Problem Formulation;

- Step 4 - Study Design and Data Quality Objective (DQO) Process;
- Step 5 - Verification of Field Sampling Design;
- Step 6 - Site Investigation and Data Analysis;
- Step 7 - Risk Characterization; and
- Step 8 - Risk Management.

Steps 1 and 2 together compose the SLERA, which is the first tier of the ERA. Screening-level assessments provide a general indication of the potential for ecological risk (USEPA, 2001). In the event that risk cannot be ruled out in the screening-level assessment, the scientific/management decision point (SMDP) indicates that the ERA progress to initiation of a Baseline Ecological Risk Assessment (BERA) at Step 3 in the assessment paradigm (Problem Formulation, discussed in Section 7.7.3 below).

The objective of a screening assessment is to identify potential chemical exposure pathways that may be present for ecological communities at the study area. These pathways are then evaluated to decide whether any of them can be eliminated from further evaluation on the basis of lack of potential for adverse ecological impacts. Three outcomes are possible from the screening-level SLERA:

- Adequate information exists to conclude that ecological risks are negligible and, therefore, there is no need for further evaluation or risk management on the basis of ecological risk.
- The available information indicates a potential for adverse ecological effects or is not adequate to evaluate whether such a potential exists. Consequently, a more thorough assessment is warranted and the ERA process will continue to Step 3. Steps 4 through 8 will be conducted, if warranted, based on the results of Steps 1 through 3.
- Interim action is warranted. This is typically followed by advancing to Step 3 of the ERA.

The screening assessment does not result in quantitative risk characterization. Only the absence (not the presence) of risk can be established by a screening assessment alone. If the possibility of risk cannot be ruled out using screening approaches, further assessment using subsequent steps in the ERA process will be required for those exposure pathways and receptor communities. The remainder of Section 7.7 focuses on Steps 1 and 2 of the ERA.

Note that as with the HHRA, the ASAOC requires the completion of a comprehensive risk assessment for the entire M&H Zinc Company Site, which will include the coordination of risk assessment activities with SulTRAC, USEPA's contractor for OU2 risk assessment. The ecological risk assessment approaches for both OUs will embrace the same general principles of risk assessment development; however, as discussed with USEPA, specific assumptions for the two OUs may vary in cases where differing site circumstances so warrant. For example, for the ecological risk assessment, the Areas of Interest (AOIs) will vary considerably between the two OUs: OU1 ecological risk assessment will be focused to a substantial degree on the Little Vermillion River, whereas the OU2 ecological risk assessment will focus on terrestrial areas.

The plan for a SLERA presented herein incorporates details discussed with USEPA and SulTRAC in a 2 May 2007 meeting.

7.7.2 Purpose and Objectives of the SLERA

The purpose of the SLERA (Steps 1 and 2) is to evaluate potential ecological risks posed by site-related chemicals, based on current site conditions and land uses. The specific objectives are to:

- identify and evaluate potential baseline ecological risks;
- define the preliminary Ecological Conceptual Site Model (ECSM);
- identify COPCs that may pose ecological risk;
- identify potential data gaps; and

- identify areas at the Site that may require further evaluation, if any, in subsequent tiers in the ecological risk assessment.

This SLERA will provide an evaluation of the nature and extent of potential ecological risks based on extensive knowledge of environmental conditions and ecological resources that may be present at the Site. Based on previous investigations, site-related COPCs may be present in some adjacent off-site aquatic habitat. Thus, potential ecological risks in relevant off-site habitat will be evaluated.

As a screening-level methodology is used, the SLERA may not be able to show that no ecological risk exists for particular COPCs and/or exposure pathways. For ecological risks that are not eliminated, the ERA process will proceed to Step 3 (Baseline Problem Formulation) where refinement to the initial screening may be proposed to eliminate COPCs or pathways. If significant ecological risks are still possible based on the results of screening refinements, further risk evaluation may be conducted (Steps 4 through 8) to evaluate ecological risks for specific media or locations.

7.7.3 Screening-Level Problem Formulation

The SLERA is initiated with a screening-level problem formulation. Problem formulation provides the basis and justification for the scope and objectives of the risk evaluation and for which specific ecological issues will be defined. When COPCs cannot be screened out of an assessment on the basis of bulk concentration, a screening-level problem formulation is developed (USEPA, 1997). The purpose of the screening-level problem formulation is to develop a screening-level conceptual model. Development of the ECSM considers:

- environmental setting and known contaminants at the Site;
- contaminant fate and transport mechanisms;
- mechanisms of ecotoxicity associated with contaminants and categories of receptors that may be affected;
- exposure pathways that may exist at the Site; and

- preliminary selection of measurement and assessment endpoints to evaluate for ecological risk.

7.7.3.1 Site Characterization and Environmental Setting

Characterization of the Site and discussion of its environmental setting are presented in Sections 1 through 7 of this Work Plan and other documents as noted in the references. The existing analytical data and data gathered during this RI/FS will be used in the SLERA in the development of the ECSM.

7.7.3.2 Receptors of Interest

Ecological receptors are the components of the ecosystem that may be adversely affected by a chemical or physical stressor. Because it is difficult to assess potential impacts to all receptors, a smaller group of representative species is selected to assess potential ecological risks to all components of the system. For aquatic areas (i.e., Little Vermilion River) benthic invertebrates, fish, and aquatic invertebrates may be selected as receptors. Representative species of mammals and birds that might utilize the off-site aquatic areas and on-site terrestrial and aquatic areas will be identified based on the presence of suitable habitat, expected presence based on range maps, representation of a range of relevant trophic groups, and availability of exposure data.

Specific descriptions of chosen receptors, their habitat requirements, and presence on the site will be presented as in further detail in the problem formulation component of the SLERA. Initially, it has been determined that there is no ecological habitat in the OU1 main plant area; hence, no ecological risk assessment will be performed for this area. Similarly, it anticipated that the slag pile terrestrial system will be generally poor habitat due to the exposed slag, although the slag pile terrestrial setting will be considered in the initial SLERA stage. Conversely, the OU1 river setting is likely to have suitable habitat for a considerable aquatic and benthic community; hence, the ERA may proceed to the comprehensive BERA stage for the river.

7.7.3.3 Chemicals of Potential Concern

The purpose of identifying COPCs is to focus the SLERA on those chemicals that may pose an ecological risk. The extent of chemicals in environmental media at the Site will be described based on analytical data collected from ecologically relevant areas of concern. The relevant data will consist of the chemical analyses of soil, sediment, and surface-water samples collected during previous investigations.

The process used for identifying COPCs in the SLERA will be consistent with current relevant guidance for risk assessment (USEPA, 1989, 1998, 2001). Chemical concentrations will be evaluated separately for each medium. An initial screening of the ecologically relevant site data against appropriate ecotoxicological threshold (ETs) values will be performed using Region 5 Ecological Screening Levels. In the absence of values for a particular parameter and receptor, other appropriate, medium-specific, conservative values representative of no-observed-adverse-effect-levels (NOAEL) will be employed. The sources for these ETs will include:

- Ecological Soil Screening Levels (Eco-SSL);
- Oak Ridge National Laboratory (ORNL) Toxicological Benchmarks for Wildlife;
- ORNL Toxicological Benchmarks for Plants;
- ORNL Toxicological Benchmarks for Soil/Litter Invertebrates;
- Ambient Water Quality Criteria (AWQC);
- Great Lakes Water Quality Initiative Tier I and II values;
- Sediment Quality Criteria (SQC);
- Sediment Quality Benchmarks (SQB); and

- National Oceanic and Atmospheric Administration's (NOAA) Effects Range Low (ERL) values

A complete set of medium-specific benchmark criteria will be compiled in conjunction with Region 5 USEPA prior to completion of the SLERA. As part of the SLERA process, additional factors (e.g., fate and transport, receptor exposure) might result in adjustment of benchmarks for selected COPCs. In such cases, the reason and justification for adopting the refined benchmark will be explicitly stated.

7.7.3.4 Assessment and Measurement Endpoints

Assessment endpoints are explicit statements of the characteristics of an ecosystem that have an intrinsic environmental value that is to be protected (USEPA, 1998a). As part of the SLERA, ecologically-based assessment endpoints relevant to the protection of receptors of interest within the Site will be developed. These assessment endpoints (used in interpreting ecological risks) involve survival, reproduction, and/or growth of receptors. Measures of effect or measurement endpoints are changes in an attribute of an assessment endpoint in response to a stressor to which it is exposed. Typical assessment endpoints and measurements of effects include aquatic and terrestrial AOIs, as presented below.

Aquatic AOIs for the SLERA will include the following:

- **Assessment Endpoint:** Survival, reproduction, and growth of fish and aquatic invertebrates.
 - SLERA Measurement Endpoint: Comparison of COPC concentrations measured in surface water to applicable AWQC and other available screening concentrations extracted from field and laboratory studies associated with adverse effects to survival, reproduction, or growth of fish and aquatic invertebrates.
- **Assessment Endpoint:** Survival, reproduction, and growth of benthic invertebrates.

- SLERA Measurement Endpoint: Comparison of COPC concentrations measured in sediment to applicable sediment quality criteria/values and other available screening concentrations extracted from field and laboratory studies associated with adverse effects to survival, reproduction, or growth of benthic invertebrates.
- **Assessment Endpoint:** Survival, reproduction, and growth of birds and mammals that utilize site aquatic habitats.
 - SLERA Measurement Endpoint: Comparison of exposure concentrations of COPCs in ingested media and food (of bird and mammal species that might feed in site aquatic habitats) to available screening concentrations associated with adverse effects to survival, reproduction, or growth of avian and mammalian species tested in the laboratory.

Slag pile terrestrial AOIs will include:

- **Assessment Endpoint:** Survival, reproduction, and growth of terrestrial plant species.
 - SLERA Measurement Endpoint: Comparison of COPC concentrations measured in surface soil to available screening concentrations extracted from field and laboratory studies associated with adverse effects to survival, reproduction, or growth of plant species.
- **Assessment Endpoint:** Survival, reproduction, and growth of terrestrial invertebrates.
 - SLERA Measurement Endpoint: Comparison of COPC concentrations measured in surface soil to available screening concentrations extracted from field and laboratory studies associated with adverse effects to survival, reproduction, and growth of soil invertebrates.

- **Assessment Endpoint:** Survival, reproduction, and growth of birds and mammals that utilize Site terrestrial habitats.
 - **SLERA Measurement Endpoint:** Comparison of exposure concentrations of COPCs in ingested media and food (of bird and mammal species that might feed in site terrestrial habitats) to available screening concentrations associated with adverse effects to survival, reproduction, or growth of avian and mammalian species tested in the laboratory.

7.7.3.5 Ecological Conceptual Site Model

An ECSM in problem formulation is a written description and visual representation of predicted relationships between ecological entities and the stressors to which they may be exposed. The ECSM displays the pathways through which receptors might be exposed to COPCs in surface water, surface soil, and sediment. The objectives of the ECSM are to:

- illustrate the ecologically significant relationships at the Site; and
- specify exposure scenarios to be evaluated in the SLERA.

The preliminary CSM will portray the direct and indirect pathways through which receptors might be exposed to COPCs in surface water, sediment, surface soil, and food.

7.7.4 **Analysis**

As part of the risk evaluation paradigm, the analysis section quantifies the magnitude, frequency, type, and duration of exposures of receptors to COPCs. In addition, information is provided to relate chemical concentrations in the relevant environmental media to adverse ecological effects. The SLERA will include Exposure Characterization and Effects Characterization. Each is described below.

7.7.4.1 Exposure Characterization

Exposure characterization involves quantifying the concentrations (or doses) of COPCs that receptors might contact via each identified exposure pathway. These concentrations (doses) will be based on either measured concentrations of COPCs in surface water, sediment, and surface soil; or estimated using empirical relationships (e.g., sediment-biota accumulation factors) to assess bioaccumulation of COPCs through the food web. From this analysis, a chemical dose and exposure concentration will be selected for each relevant pathway. Initial screening will assume that ecological receptors spend 100% of their time exposed to site COPCs. If warranted, the SLERA refinement step will make use of appropriate species-specific area use factors to better characterize actual exposure at the Site.

7.7.4.2 Effects Characterization

Effects characterization involves quantifying the concentrations (or doses) of COPCs that might be associated with adverse effects. The effects characterization levels will be compared with the potential dose levels identified in the exposure characterization to evaluate the likelihood of an adverse ecological effect to site-specific chemicals in the ecologically relevant environmental media at the Site.

Maximum site concentrations of a contaminant will be compared to the selected ET. When concentrations do not exceed the ET, the contaminant will be excluded from further consideration as a COPC. However, if the concentration is greater than the ET, the chemical does not necessarily pose an ecological risk to site receptors. The chemical warrants further analysis before it is selected as a COPC. If the concentration is greater than the ET, the chemical is retained as a potential COPC for further analysis.

Due to the extent of site data available and results from previous investigations, it is anticipated that the SLERA will result in one or more organic and inorganic constituents being retained as preliminary COPCs. Following the comparison of maximum concentrations to ETs, data will be processed to characterize the distribution of the data, evaluate and characterize the “non-detect” values so as to select the most appropriate

representative numeric value, and to summarize the data statistically. The final COPC selection process will consider the following factors:

- whether the detected chemical is a common laboratory contaminant;
- the detection frequency;
- comparison of site chemical concentrations to local background concentrations as discussed in Section 7.6.4.2;
- comparison of site concentration data to appropriate screening level benchmarks; and
- consideration of the chemical's bioaccumulative potential.

7.7.5 Screening-Level Risk Characterization

Risk characterization is the integration of exposure and effects information to identify the nature and extent of ecological risks and interpretation of the significance of the indicated risk, based on quantitative risk levels and degree of uncertainty. Following USEPA guidance, the SLERA risk characterization will include risk estimation, uncertainty analysis, and risk interpretation.

In the risk estimation, the mathematical relationship between exposure levels and effects levels for each combination of COPC, exposure pathway, and receptor are presented. A HQ approach will be applied by dividing the estimated exposure concentration or dose of the COPC in the specific medium by a concentration or dose which is not expected to pose a significant ecological risk (i.e., toxicity reference value). A HQ equal to or less than 1 indicates no significant ecological risk for the particular COPC, exposure pathway, and receptor, while a HQ greater than 1 indicates that the COPC will require further evaluation in the later stages of the risk assessment (i.e., BERA).

An uncertainty analysis that identifies uncertainty and variability in the exposure and effects characterizations will be performed to characterize factors influencing the risk estimates. Risk interpretation will be based on the results of the risk estimation and the

uncertainty analysis. The interpretation will use multiple lines of evidence (i.e., “weight-of-evidence”), including risk estimates, spatial considerations, uncertainty analysis, and site-specific data. Risk interpretation will conclude with the identification of receptors, AOIs, and COPCs, if any, that require further evaluation in the BERA.

7.7.6 Risk Management and Additional Evaluation

The stepwise approach proposed for risk evaluation at the Site incorporates potential decision-making points that are used for risk management and to guide the direction of additional risk evaluation. These risk decisions form the culmination of Steps 1 and 2, and the potential initiation of Step 3. Risk interpretation (summarizing the risk characterization results, uncertainty, and weight-of-evidence) from each tier is used to decide whether further evaluation is required for a particular medium or area. If no risks are indicated, then no further risk evaluation is required. If ecological risks are indicated or there are data gaps in the SLERA that prevent risk characterization of pathways or COPCs, then further evaluation may be warranted. Remedial actions may be proposed at any point during the risk evaluation process, if sufficient evidence indicates that further risk evaluation is not needed to establish the nature and extent of potential adverse risks and possible remedies seem obvious.

The results of the SLERA will lead to:

- no further action;
- initiation of a BERA; or
- potential remedial action.

7.7.7 Baseline Ecological Risk Assessment

If the need for a second-tier BERA is indicated, it will provide a much more detailed and geographic area-medium-specific approach in the scope and nature of its assessment and measurement endpoints. A BERA incorporates site-specific data, biota, and exposure pathways, with less reliance on conservative literature values or generic assumptions used in the SLERA. Data used in the SLERA will be reviewed to evaluate

whether additional data are needed to conduct the BERA. In the event that a BERA requiring additional data collection is necessary, a work plan will be prepared and submitted to USEPA for review.

A BERA may include additional, detailed habitat characterization, field surveys, fate and transport modeling, toxicity testing, food-web modeling, bioavailability studies, community structure and population studies, or other field or analytical investigations. The evaluation may use several measurement endpoints to evaluate the assessment endpoints and integrate the results in a weight-of-evidence approach. At the second stage of risk management, the results of the BERA will be used to evaluate the need for additional potential ecological risk evaluation, or if risk is indicated, whether remedial activities may be warranted for specific areas or media.

Note that on the basis of discussions in the 2 May 2007 meeting with USEPA and SulTRAC, it is likely that the slag pile terrestrial AOIs will be addressed in an SMDP at the conclusion of the initial stages of the SLERA; hence, terrestrial AOIs are not likely to be considered in a BERA. As such, if a BERA is necessary, it will most likely focus exclusively on river-related receptors.

The BERA refines the SLERA by considering site-specific information in the problem formulation step. Problem formulation at Step 3 includes several activities:

- refining preliminary contaminants of ecological concern;
- further characterizing ecological effects of contaminants;
- reviewing and refining information on contaminant fate and transport, complete exposure pathways, and ecosystems potentially at risk;
- selecting assessment endpoints; and
- developing a conceptual model with working hypotheses or questions about the site.

The assessment endpoints, which have been refined based on the SLERA, habitat characterization, and discussions with USEPA and SulTRAC, are then used to develop a work plan where the relevant measurement endpoints will be described.

Measurement endpoints can include direct measures of exposure (e.g., contaminant concentration in surface water or sediment) or measures of effects (e.g., toxicity tests or community diversity measures). These measurement endpoints can be compared to reference, or background, conditions to evaluate the ecological risk at the site. It is often appropriate for more than one measurement to be used to evaluate a specific assessment endpoint. A “weight of evidence” approach is used to look at multiple measurement endpoints. For example, a common approach used to evaluate the benthic community (as an assessment endpoint) is the sediment “triad” approach, which incorporates chemical data with toxicity data and community structure information.

Based on research into likely species present in the site vicinity and initial discussions with USEPA and SulTRAC, tentative receptors of interest have been identified in the event that a BERA is necessary. Aquatic assessment endpoints will include vertebrate species such as smallmouth bass (*Micropterus dolomieu*) as a prey species and walleye (*Sander vitreus vitreus*) as a predator species. The benthic invertebrate assessment endpoint will be the midge (*Chironomus riparius*). The mammalian receptor of interest will be the raccoon (*Procyon lotor*), and avian receptors of interest will be the green heron (*Butorides striatus*) and belted kingfisher (*Ceryle alcyon*.)

If a BERA is required, data assessment will consider multiple lines of evidence, including a comparison of fish tissue data to toxicological reference concentrations for (i) the fish as an endpoint as well as (ii) mammalian and avian receptors as separate endpoints. Where applicable, area use factors will be applied to compensate for the broader feeding range of mammalian and avian receptors. Toxicity testing data and community population/structure findings, of which both will be compared to those of reference stations, will provide evidence of any community impairment. These assessments, in concert with a review of primary surface-water and sediment data, will constitute a weight-of-evidence assessment of the overall health of the ecological community.

7.8 Surface-Water Basin Analyses

Since OU1 includes the Little Vermilion River, contributions to the river from overland flow emanating from both OU1 and OU2 will be evaluated during the surface-water basin analyses. The purpose of the basin analyses is to evaluate the total contributing area of surface-water flows as well as defining the drainage network. Combining these data will help to provide a fundamental understanding of potential surface-water contributions and areas of enhanced sediment transport.

The first phase of the basin analyses will require the acquisition of appropriate GIS coverages and includes all available information relative to local scale topography, hydrologic features, and digital raster graphics (i.e., USGS 1:24,000 quadrangles). These data will provide the basis for subsequent land-surface elevational modeling and eventual basin delineations.

Site topographic features will be utilized to develop an initial Digital Elevation Model (DEM) and then integrated into a USGS DEM. Merging these datasets will insure a greater degree of confidence in the development of the land surface rasters since the USGS DEM will likely include average land surface measurements on a regularized 30 by 30 meter spacing.

An initial basin delineation will then be completed using the existing topographic features and then post-processed using ArcMap/Spatial analyst extension. A hydrologic modeling tool is embedded within the extension and allows for a rapid assessment of a number of hydrologic features including; a watershed analysis (i.e., basin delineation), drainage network evaluation, and hill slope analyses. Post processing of these data as well as “truthing” to initial basin delineations insures that oversimplification and obscuring of small-scale hydrologic features are reduced and/or eliminated. These techniques are typically referred to as “stream burning”. These techniques can be utilized to define large and small-scale drainage features as long as these vector hydrography features are overlain.

Incorporation of vector hydrography and appropriate analytical techniques will help to estimate both the contributing areas and drainage network for OU1 and OU2. These

data are an important component of an initial surface-water analyses and will provide a fundamental understanding of the local hydrography.

7.9 Remedial Investigation Report

In accordance with Task 4 of the ASAO, an RI Report will be written to comprehensively present the findings of the RI, including the investigative scope performed, the site characteristics, the refined CSM, the nature and extent of contamination, and the results of the human health and ecological risk assessments. In accordance with Appendix A of the ASAO, Carus will be responsible for combining all sections of the RI document into one comprehensive report.

As with the performance of the risk assessments, the RI reporting will be a joint effort with SulTRAC, who will provide corresponding information for OU2. Geosyntec will work closely with SulTRAC to coordinate sharing of data and information. Carus is responsible for assembling the RI Report, which will include the OU2 information provided by SulTRAC, as well as the information developed by Geosyntec for OU1. The joint effort will result in a comprehensive report for the M&H Zinc Company Site as a whole.

8. FEASIBILITY STUDY SCOPE OF WORK

8.1 Overview

Upon completion and submission of a RI Report for the entire site, Carus will prepare and submit a work plan for a FS for OU1. The FS to be described in the work plan will contain the following components:

- **Development of Remedial Alternatives:** This process begins with a refinement of the RAOs noted in Section 5. The RAOs will be refined through RI site characterization and risk assessment, of which both will narrow the scope of chemicals, pathways, and receptors of concern. Additionally, PRGs will be refined as a result of the risk assessment in the RI, which will provide quantitative levels of acceptable exposure concentrations. These PRGs will also be affected by the early stages of the FS, in which the preliminary list of ARARs will be refined. For each release of concern, broad technical approaches to remediation, such as *in situ* remediation vs. physical containment, will be proposed. Additionally, a rough scope of implementation will be estimated. For example, this may include area estimates for capping, etc.
- **Screening of Remedial Alternatives:** In this step of the FS, for each broad technical remedial approach proposed as above, specific technologies within the broad approach are proposed and either retained for further consideration or eliminated. For example, if *in situ* remediation is proposed in the first step, the second step may lead to the elimination of aerobic remediation as one specific option and the retention of anaerobic remediation as a viable option based on groundwater geochemistry or the specific nature of the chemical of concern.
- **Detailed Analysis of Alternatives:** In the third major phase of the FS process, the understanding and scoping of viable remedial alternatives is augmented through the incorporation of treatability study insights, as needed, (see next section) and a more detailed scoping of the remedy than is presented in the Development of Remedial Alternatives. Given this information, the alternatives are tested against the following nine criteria (USEPA, 1988):

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume;
- short-term effectiveness;
- implementability;
- cost;
- state acceptance; and
- community acceptance.

In addition to evaluating each alternative with respect to a given criterion, this section of the analysis compares the alternatives to one another with respect to their individual ability to meet a given criterion.

Note that as with relevant portions of the RI, the FS will be a coordinated activity between Carus and USEPA and their contractors for OU1 and OU2 to the extent that remedy considerations are applicable to the site as a whole. The FS report, described in more detail in Section 8.3, will conclude with a recommendation for comprehensive, sitewide remedy.

8.2 Treatability Studies

Treatability studies will be conducted, as needed, and may include bench-scale (i.e., laboratory testing) and pilot studies (i.e., field testing). Microcosms are an example of the former, while a single-well, short-term soil vapor extraction (SVE) test on-site is an example of the latter. Treatability studies allow the respondents to decrease the uncertainty inherent in remedial decisions by providing data and observations that are pertinent to determining the appropriateness of a given technology for the site. This may be necessary if data collected for the RI are insufficient to decide whether a given

method is feasible. For example, it is not possible to confirm the radius of influence of an SVE system without direct observation through pilot testing.

The need for a treatability study will be evaluated using an informal cost-benefit analysis. It is conceivable that for a given remedial need, two technologies, one being conventional and high-cost and the second being innovative and low-cost, may be retained. If the innovative technology represents a significant cost savings over the conventional approach, yet significant uncertainty exists pertaining to its site-specific effectiveness (perhaps due to a limited track record), a treatability study may be proposed.

Treatability studies, if deemed necessary, will begin with the securing of regulatory approval through the submittal of: (i) an Identification of Candidate Technologies Memorandum; (ii) a Treatability Testing Statement of Work; and (iii) a Treatability Testing Work Plan. The work plan will include supplemental HASP or FSP components, as needed.

Upon completion of the field or laboratory testing, treatability study reports will be prepared for the regulatory agencies, as needed.

8.3 Feasibility Study Report

In accordance with Task 7 of the ASAOC, a comprehensive FS Report will be prepared. The report will document the development, screening, and comparative analysis of remedial alternatives and will provide sufficient information for USEPA to issue a Record of Decision (ROD) for the site. In accordance with Appendix A of the ASAOC, Carus will be responsible for combining all sections of the FS document into one comprehensive report; however, as described under Task 7 of Appendix A of the ASAOC, to the extent the remedial alternatives under consideration address both OU1 and OU2, USEPA and its contractor will evaluate the alternative with input from the Respondent (Carus), unless the Respondent decides at that time it prefers to evaluate the alternative with input from USEPA and its contractor.

As with the RI report, the FS Report will be a joint effort with SulTRAC, who will provide corresponding information for OU2. The joint effort will result in a comprehensive report for the M&H Zinc Company Site as a whole.

9. PROJECT MANAGEMENT AND CONTROL

9.1 Data Management Plan

In accordance with USEPA Region 5 requirements, Carus has developed a relational database consistent with the specifications found at <http://www.epa.gov/region5superfund/edman/index.html>. The specification includes a series of data tables for different data components. The data tables include the following:

- chemistry field measurements;
- extraction/injection wells;
- groundwater levels;
- locations;
- site information;
- sample IDs;
- chemical test results;
- chemical test results with QC data; and
- wells.

Field descriptions for the aforementioned nine tables appear in Table 7 of this document.

The database of historical data that has been developed per this specification has been used to support the data analyses and Geographic Information System (GIS) work products used in this work plan. Concurrent with the Planning Documents, the current database as flat files per Region 5 specifications is being submitted (provided as CD in Appendix E).

The analytical laboratory selected for this project, Columbia Analytical Services – Rochester (NY), will provide data in an electronic data deliverable (EDD) that is consistent with Region 5 EDD requirements. Electronic updates will be submitted to the USEPA through data submittals, as part of the Monthly Progress Report requirements, as the investigation is performed.

9.2 Schedule

The ASAO requires that the RI/FS Planning Documents include the schedule for submission of the RI Report (draft and final), Risk Assessment Reports, Treatability Study Reports, FS Reports, and all other deliverables deemed appropriate by the USEPA. The proposed schedule for the RI/FS activities is presented as Figure 14. Figure 14 includes a schedule for the deliverables presented above, as well as a schedule for the RI fieldwork and a technical memorandum to present the results of the monitoring well network reconnaissance and a proposal for additional groundwater monitoring wells, if warranted. Implementation of the RI/FS will require close coordination with the USEPA oversight contractor and contractor responsible for OU2 (SulTRAC). As such, the proposed schedule may require modification to ensure that components of the fieldwork (e.g., groundwater sampling) are scheduled concurrently between OU1 and OU2 to maximize the value of the data. In addition, the ASAO requires that the Respondent and USEPA (represented by Geosyntec and SulTRAC, respectively) cooperate with each other to jointly produce documents required by the ASAO. Although submittal dates for the RI Report (draft and final), Risk Assessment Reports, Treatability Study Reports, and FS Reports are proposed within the schedule, actual deliverable dates will be impacted not only by the completion of work performed by Geosyntec at OU1, but also by the completion of work performed by SulTRAC at OU2.

If, at any time during the RI/FS process, unanticipated conditions or changed circumstances are discovered which may result in a schedule delay, the Respondent shall bring such information to the attention of the USEPA for consideration as it may affect the proposed schedule. Completion times shown in the schedule are calendar days. Any deadline which falls on a holiday or weekend will be extended to the next business day.

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TABLES

Table 1. Summary of Hydraulic Conductivity Data
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Well/ Piezometer	Hydraulic Conductivity		Remarks
	(cm/sec)	(ft/min)	
P-6	1.6×10^{-4}	3.2×10^{-4}	Slug Test
P-7	9.5×10^{-5}	1.9×10^{-4}	Slug Test
P-9	5.0×10^{-4}	1.0×10^{-3}	Slug Test
P-15	4.6×10^{-6}	9.1×10^{-5}	Slug Test
P-17	$\sim 5 \times 10^{-3}$	$\sim 1 \times 10^{-2}$	Pump Test
P-18	2.2×10^{-2}	4.3×10^{-2}	Slug test
P-18	$\sim 4 \times 10^{-2}$	8×10^{-2}	Pump Test
MW- 1	$\sim 2 \times 10^{-1}$	$\sim 4 \times 10^{-1}$	Pump Test
MW-1	$*5.7 \times 10^{-2}$	$*1.1 \times 10^{-1}$	Slug Test
MW-2	$\sim 7 \times 10^{-3}$	1×10^{-2}	Pump Test
G-02	4.0×10^{-6}	7.9×10^{-5}	Slug Test
G-04	2.7×10^{-3}	5.4×10^{-3}	Slug Test
G-05	2.0×10^{-3}	4.0×10^{-3}	Slug Test

Notes:

1. Slug tests and pump tests were performed during the 1994 Investigation following groundwater sampling. Slug test data were analyzed using the Bouwer and Rice model. Pump test data were analyzed using the Theis equation.
2. "*" indicates a second set of data for the same well.

Table 2a. Solid Matrix Screening by Submedium and Priority Metals Determination
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample Matrix	Criterion	Parameter	Standard	Fill	Road Gravel	Shale	Sinter	Surface Soil	Slag	Alluvium
Soil	ECO SLs REG 5	Aluminum		0/2/2, Avg: 7450, Max: 9560	0/3/3, Avg: 8750, Max: 12400	0/3/3, Avg: 13500, Max: 15000	0/1/1, Avg: 12900, Max: 12900	0/2/3, Avg: 9500, Max: 17600	0/7/7, Avg: 18500, Max: 35300	
Soil	ECO SLs REG 5	Antimony	0.14	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	1/1/4, Avg: 7.6, Max: 30.4	
Soil	ECO SLs REG 5	Arsenic	5.7	0/2/2, Avg: 3.9, Max: 5.4	2/3/3, Avg: 12.1, Max: 21.1	0/2/3, Avg: 2.3, Max: 4.0	0/1/1, Avg: 3.0, Max: 3.0	1/2/3, Avg: 10.8, Max: 27.1	7/7/7, Avg: 68.1, Max: 245	
Soil	ECO SLs REG 5	Barium	1.0	2/2/2, Avg: 39.3, Max: 53.0	3/3/3, Avg: 145, Max: 217	3/3/3, Avg: 86.0, Max: 179	1/1/1, Avg: 107, Max: 107	3/3/4, Avg: 109, Max: 159	21/21/21, Avg: 216, Max: 820	2/2/2, Avg: 111, Max: 189
Soil	ECO SLs REG 5	Beryllium	1.1	0/2/2, Avg: 0.50, Max: 0.66	0/3/3, Avg: 0.76, Max: 0.97	2/3/3, Avg: 0.92, Max: 1.1	0/1/1, Avg: 0.88, Max: 0.88	1/2/2, Avg: 0.99, Max: 1.1	7/7/7, Avg: 3.5, Max: 12.7	
Soil	ECO SLs REG 5	Cadmium	0.0022	1/1/2, Avg: 1.4, Max: 2.7	2/2/3, Avg: 16.0, Max: 38.3	2/2/3, Avg: 7.3, Max: 20.9	1/1/1, Avg: 8.4, Max: 8.4	3/3/4, Avg: 11.6, Max: 22.3	21/21/21, Avg: 39.3, Max: 228	2/2/2, Avg: 26.3, Max: 45.4
Soil	ECO SLs REG 5	Calcium		0/2/2, Avg: 61500, Max: 66200	0/3/3, Avg: 38300, Max: 62300	0/3/3, Avg: 73300, Max: 103000	0/1/1, Avg: 38600, Max: 38600	0/3/3, Avg: 39300, Max: 64400	0/6/7, Avg: 24900, Max: 50700	
Soil	ECO SLs REG 5	Chromium	0.40	2/2/2, Avg: 12.1, Max: 14.4	3/3/3, Avg: 27.6, Max: 44.2	3/3/3, Avg: 30.0, Max: 40.0	1/1/1, Avg: 20.7, Max: 20.7	3/3/3, Avg: 25.6, Max: 29.7	21/21/21, Avg: 25.0, Max: 97.5	2/2/2, Avg: 10.2, Max: 11.7
Soil	ECO SLs REG 5	Cobalt	0.14	2/2/2, Avg: 9.0, Max: 9.5	3/3/3, Avg: 14.3, Max: 16.0	3/3/3, Avg: 11.8, Max: 16.4	2/2/2, Avg: 17.4, Max: 20.9	5/5/7, Avg: 10.7, Max: 46.4		
Soil	ECO SLs REG 5	Copper	5.4	2/2/2, Avg: 18.8, Max: 20.3	3/3/3, Avg: 101, Max: 232	3/3/3, Avg: 29.4, Max: 46.8	1/1/1, Avg: 38.9, Max: 38.9	3/3/3, Avg: 160, Max: 409	7/7/7, Avg: 922, Max: 4340	
Soil	ECO SLs REG 5	Iron		0/2/2, Avg: 16600, Max: 16700	0/3/3, Avg: 31100, Max: 59100	0/3/3, Avg: 14800, Max: 25700	0/1/1, Avg: 18700, Max: 18700	0/3/3, Avg: 25700, Max: 39500	0/18/21, Avg: 38700, Max: 209000	0/2/2, Avg: 50000, Max: 60300
Soil	ECO SLs REG 5	Lead	0.054	2/2/2, Avg: 16.6, Max: 18.6	3/3/3, Avg: 1290, Max: 3660	3/3/3, Avg: 178, Max: 510	1/1/1, Avg: 225, Max: 225	3/3/4, Avg: 135, Max: 324	21/21/21, Avg: 2600, Max: 38700	2/2/2, Avg: 26.7, Max: 47.9
Soil	ECO SLs REG 5	Magnesium		0/2/2, Avg: 24400, Max: 36300	0/3/3, Avg: 9100, Max: 12000	0/3/3, Avg: 7790, Max: 11700	0/1/1, Avg: 6580, Max: 6580	0/3/3, Avg: 19300, Max: 35600	0/4/4, Avg: 1460, Max: 2390	
Soil	ECO SLs REG 5	Manganese		0/2/2, Avg: 498, Max: 600	0/3/3, Avg: 2330, Max: 3980	0/3/3, Avg: 1140, Max: 1560	0/1/1, Avg: 1350, Max: 1350	0/4/4, Avg: 32700, Max: 118000	0/20/21, Avg: 2680, Max: 40600	0/2/2, Avg: 1440, Max: 2030
Soil	ECO SLs REG 5	Mercury	0.10	0/0/2, Avg: 0.0, Max: 0.0	2/2/3, Avg: 0.85, Max: 1.8	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	2/2/4, Avg: 0.085, Max: 0.19	7/7/21, Avg: 0.37, Max: 2.3	0/0/2, Avg: 0.0, Max: 0.0
Soil	ECO SLs REG 5	Nickel	13.6	2/2/2, Avg: 25.8, Max: 29.4	3/3/3, Avg: 29.8, Max: 37.1	3/3/3, Avg: 35.1, Max: 48.6	1/1/1, Avg: 36.7, Max: 36.7	4/4/4, Avg: 36.1, Max: 48.2	13/20/21, Avg: 36.1, Max: 119	2/2/2, Avg: 28.8, Max: 37.7
Soil	ECO SLs REG 5	Potassium		0/2/2, Avg: 1730, Max: 2210	0/3/3, Avg: 3050, Max: 4670	0/3/3, Avg: 2540, Max: 2740	0/1/1, Avg: 3010, Max: 3010	0/2/3, Avg: 6520, Max: 13500	0/5/7, Avg: 2920, Max: 8100	
Soil	ECO SLs REG 5	Selenium	0.028	0/0/2, Avg: 0.0, Max: 0.0	2/2/3, Avg: 2.0, Max: 3.5	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	2/2/7, Avg: 6.5, Max: 27.7	
Soil	ECO SLs REG 5	Silver	4.0	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	1/1/3, Avg: 6.9, Max: 20.6	1/1/7, Avg: 2.6, Max: 18.0	
Soil	ECO SLs REG 5	Sodium		0/0/2, Avg: 0.0, Max: 0.0	0/2/3, Avg: 302, Max: 572	0/2/3, Avg: 309, Max: 591	0/1/1, Avg: 356, Max: 356	0/2/2, Avg: 6640, Max: 7600	0/7/7, Avg: 1050, Max: 1440	
Soil	ECO SLs REG 5	Thallium	0.057	1/1/2, Avg: 0.12, Max: 0.24	1/1/3, Avg: 0.083, Max: 0.25	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	2/2/7, Avg: 0.24, Max: 0.98	
Soil	ECO SLs REG 5	Vanadium	1.6	2/2/2, Avg: 11.5, Max: 12.3	2/3/3, Avg: 16.3, Max: 28.1	3/3/3, Avg: 24.0, Max: 30.0	1/1/1, Avg: 16.3, Max: 16.3	2/2/2, Avg: 28.0, Max: 40.3	5/5/7, Avg: 36.0, Max: 110	
Soil	ECO SLs REG 5	Zinc	6.6	2/2/2, Avg: 257, Max: 443	3/3/3, Avg: 3660, Max: 8550	3/3/3, Avg: 158, Max: 390	1/1/1, Avg: 4130, Max: 4130	3/3/4, Avg: 1480, Max: 3030	21/21/21, Avg: 11900, Max: 43700	2/2/2, Avg: 11200, Max: 21800
Soil	PRG INDUSTRIAL REG 9	Aluminum	100000	0/2/2, Avg: 7450, Max: 9560	0/3/3, Avg: 8750, Max: 12400	0/3/3, Avg: 13500, Max: 15000	0/1/1, Avg: 12900, Max: 12900	0/2/3, Avg: 9500, Max: 17600	0/7/7, Avg: 18500, Max: 35300	
Soil	PRG INDUSTRIAL REG 9	Antimony	410	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/1/4, Avg: 7.6, Max: 30.4	
Soil	PRG INDUSTRIAL REG 9	Arsenic	1.6	2/2/2, Avg: 3.9, Max: 5.4	3/3/3, Avg: 12.1, Max: 21.1	2/2/3, Avg: 2.3, Max: 4.0	1/1/1, Avg: 3.0, Max: 3.0	2/2/3, Avg: 10.8, Max: 27.1	7/7/7, Avg: 68.1, Max: 245	
Soil	PRG INDUSTRIAL REG 9	Barium	67000	0/2/2, Avg: 39.3, Max: 53.0	0/3/3, Avg: 145, Max: 217	0/3/3, Avg: 86.0, Max: 179	0/1/1, Avg: 107, Max: 107	0/3/4, Avg: 109, Max: 159	0/21/21, Avg: 216, Max: 820	0/2/2, Avg: 111, Max: 189
Soil	PRG INDUSTRIAL REG 9	Beryllium	1900	0/2/2, Avg: 0.50, Max: 0.66	0/3/3, Avg: 0.76, Max: 0.97	0/3/3, Avg: 0.92, Max: 1.1	0/1/1, Avg: 0.88, Max: 0.88	0/2/2, Avg: 0.99, Max: 1.1	0/7/7, Avg: 3.5, Max: 12.7	
Soil	PRG INDUSTRIAL REG 9	Cadmium	450	0/1/2, Avg: 1.4, Max: 2.7	0/2/3, Avg: 16.0, Max: 38.3	0/2/3, Avg: 7.3, Max: 20.9	0/1/1, Avg: 8.4, Max: 8.4	0/3/4, Avg: 11.6, Max: 22.3	0/21/21, Avg: 39.3, Max: 228	0/2/2, Avg: 26.3, Max: 45.4
Soil	PRG INDUSTRIAL REG 9	Calcium		0/2/2, Avg: 61500, Max: 66200	0/3/3, Avg: 38300, Max: 62300	0/3/3, Avg: 73300, Max: 103000	0/1/1, Avg: 38600, Max: 38600	0/3/3, Avg: 39300, Max: 64400	0/6/7, Avg: 24900, Max: 50700	
Soil	PRG INDUSTRIAL REG 9	Chromium	450	0/2/2, Avg: 12.1, Max: 14.4	0/3/3, Avg: 27.6, Max: 44.2	0/3/3, Avg: 30.0, Max: 40.0	0/1/1, Avg: 20.7, Max: 20.7	0/3/3, Avg: 25.6, Max: 29.7	0/21/21, Avg: 25.0, Max: 97.5	0/2/2, Avg: 10.2, Max: 11.7
Soil	PRG INDUSTRIAL REG 9	Chromium	64.0	0/2/2, Avg: 12.1, Max: 14.4	0/3/3, Avg: 27.6, Max: 44.2	0/3/3, Avg: 30.0, Max: 40.0	0/1/1, Avg: 20.7, Max: 20.7	0/3/3, Avg: 25.6, Max: 29.7	1/21/21, Avg: 25.0, Max: 97.5	0/2/2, Avg: 10.2, Max: 11.7
Soil	PRG INDUSTRIAL REG 9	Cobalt	1900	0/2/2, Avg: 9.0, Max: 9.5	0/3/3, Avg: 14.3, Max: 16.0	0/3/3, Avg: 11.8, Max: 16.4	0/1/1, Avg: 15.0, Max: 15.0	0/2/2, Avg: 17.4, Max: 20.9	0/5/7, Avg: 10.7, Max: 46.4	
Soil	PRG INDUSTRIAL REG 9	Copper	41000	0/2/2, Avg: 18.8, Max: 20.3	0/3/3, Avg: 101, Max: 232	0/3/3, Avg: 29.4, Max: 46.8	0/1/1, Avg: 38.9, Max: 38.9	0/3/3, Avg: 160, Max: 409	0/7/7, Avg: 922, Max: 4340	
Soil	PRG INDUSTRIAL REG 9	Iron	100000	0/2/2, Avg: 16600, Max: 16700	0/3/3, Avg: 31100, Max: 59100	0/3/3, Avg: 14800, Max: 25700	0/1/1, Avg: 18700, Max: 18700	0/3/3, Avg: 25700, Max: 39500	1/18/21, Avg: 38700, Max: 209000	0/2/2, Avg: 50000, Max: 60300
Soil	PRG INDUSTRIAL REG 9	Lead	800	0/2/2, Avg: 16.6, Max: 18.6	1/3/3, Avg: 1290, Max: 3660	0/3/3, Avg: 178, Max: 510	0/1/1, Avg: 225, Max: 225	0/3/4, Avg: 135, Max: 324	8/21/21, Avg: 2600, Max: 38700	0/2/2, Avg: 26.7, Max: 47.9
Soil	PRG INDUSTRIAL REG 9	Magnesium		0/2/2, Avg: 24400, Max: 36300	0/3/3, Avg: 9100, Max: 12000	0/3/3, Avg: 7790, Max: 11700	0/1/1, Avg: 6580, Max: 6580	0/3/3, Avg: 19300, Max: 35600	0/4/4, Avg: 1460, Max: 2390	
Soil	PRG INDUSTRIAL REG 9	Manganese	19000	0/2/2, Avg: 498, Max: 600	0/3/3, Avg: 2330, Max: 3980	0/3/3, Avg: 1140, Max: 1560	0/1/1, Avg: 1350, Max: 1350	1/4/4, Avg: 32700, Max: 118000	1/20/21, Avg: 2680, Max: 40600	0/2/2, Avg: 1440, Max: 2030
Soil	PRG INDUSTRIAL REG 9	Mercury		0/0/2, Avg: 0.0, Max: 0.0	0/2/3, Avg: 0.85, Max: 1.8	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/2/4, Avg: 0.085, Max: 0.19	0/7/21, Avg: 0.37, Max: 2.3	0/0/2, Avg: 0.0, Max: 0.0
Soil	PRG INDUSTRIAL REG 9	Nickel	20000	0/2/2, Avg: 25.8, Max: 29.4	0/3/3, Avg: 29.8, Max: 37.1	0/3/3, Avg: 35.1, Max: 48.6	0/1/1, Avg: 36.7, Max: 36.7	0/4/4, Avg: 36.1, Max: 48.2	0/20/21, Avg: 36.1, Max: 119	0/2/2, Avg: 28.8, Max: 37.7
Soil	PRG INDUSTRIAL REG 9	Potassium		0/2/2, Avg: 1730, Max: 2210	0/3/3, Avg: 3050, Max: 4670	0/3/3, Avg: 2540, Max: 2740	0/1/1, Avg: 3010, Max: 3010	0/2/3, Avg: 6520, Max: 13500	0/5/7, Avg: 2920, Max: 8100	
Soil	PRG INDUSTRIAL REG 9	Selenium	5100	0/0/2, Avg: 0.0, Max: 0.0	0/2/3, Avg: 2.0, Max: 3.5	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/2/7, Avg: 6.5, Max: 27.7	
Soil	PRG INDUSTRIAL REG 9	Silver		0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/1/3, Avg: 6.9, Max: 20.6	0/1/7, Avg: 2.6, Max: 18.0	
Soil	PRG INDUSTRIAL REG 9	Sodium		0/0/2, Avg: 0.0, Max: 0.0	0/2/3, Avg: 302, Max: 572	0/2/3, Avg: 309, Max: 591	0/1/1, Avg: 356, Max: 356	0/2/2, Avg: 6640, Max: 7600	0/7/7, Avg: 1050, Max: 1440	
Soil	PRG INDUSTRIAL REG 9	Thallium		0/1/2, Avg: 0.12, Max: 0.24	0/1/3, Avg: 0.083, Max: 0.25	0/0/3, Avg: 0.0, Max: 0.0	0/0/1, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/2/7, Avg: 0.24, Max: 0.98	
Soil	PRG INDUSTRIAL REG 9	Vanadium	1000	0/2/2, Avg: 11.5, Max: 12.3	0/3/3, Avg: 16.3, Max: 28.1	0/3/3, Avg: 24.0, Max: 30.0	0/1/1, Avg: 16.3, Max: 16.3	0/2/2, Avg: 28.0, Max: 40.3	0/5/7, Avg: 36.0, Max: 110	
Soil	PRG INDUSTRIAL REG 9	Zinc	100000	0/2/2, Avg: 257, Max: 443	0/3/3, Avg: 3660, Max: 8550	0/3/3, Avg: 158, Max: 390	0/1/1, Avg: 4130, Max: 4130	0/3/4, Avg: 1480, Max: 3030	0/21/21, Avg: 11900, Max: 43700	0/2/2, Avg: 11200, Max: 21800

Rank	Description
-	Data not available
0	Not Detected
1	Detected - No Standard (Unknown Risk)
2	Detected - Below Standard (Low Risk)
3	Exceeds Standard (Medium Risk)
4	Exceeds 5 x Standard (Higher Risk)

Ecological scenario priority metals:
High priority: antimony, arsenic, beryllium, mercury, nickel, selenium, thallium, zinc. Selected for higher risk categorization that is dominant in slag. Zinc receives high priority designation due to dominant concentrations in slag.
Medium priority: barium, cadmium, chromium, cobalt, copper, lead, silver, vanadium. Selected for higher risk category metals that are consistent across submedia.

Human health scenario priority metals:
High priority: arsenic, lead, manganese. Selected if higher risk in any submedium.
Medium priority: chromium, iron. Selected if medium risk in any submedium.

- Note:
1. All units are mg/kg.
2. Summary values are (number of exceedances)/(number of detections)/(number of data records), arithmetic average, maximum.

Table 2b. Groundwater Screening by Submedium and Priority Metals Determination
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample Matrix	Criterion	Parameter	Standard	Alluvium	Fill	Shale	Till	Slag	Unknown
Groundwater	ECO SLs REG 5 x 10	Aluminum			0/1/2, Avg: 3.2, Max: 6.3	0/2/4, Avg: 12.3, Max: 48.3	0/1/2, Avg: 61.5, Max: 123	0/3/4, Avg: 14.8, Max: 55.0	0/3/3, Avg: 10.0, Max: 25.8
Groundwater	ECO SLs REG 5 x 10	Antimony	0.80		0/0/1, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/1/2, Avg: 0.041, Max: 0.081
Groundwater	ECO SLs REG 5 x 10	Arsenic	1.5		0/2/2, Avg: 0.0041, Max: 0.0055	0/5/6, Avg: 0.0048, Max: 0.021	0/6/8, Avg: 0.0030, Max: 0.0071	0/7/7, Avg: 0.0060, Max: 0.0090	0/4/4, Avg: 0.013, Max: 0.022
Groundwater	ECO SLs REG 5 x 10	Barium	2.2	0/2/2, Avg: 0.020, Max: 0.025	0/2/2, Avg: 0.089, Max: 0.13	0/8/9, Avg: 0.067, Max: 0.36	1/10/10, Avg: 0.52, Max: 2.5	0/10/10, Avg: 0.13, Max: 0.38	0/5/5, Avg: 0.36, Max: 1.1
Groundwater	ECO SLs REG 5 x 10	Beryllium	0.036		0/0/1, Avg: 0.0, Max: 0.0	0/1/3, Avg: 0.00067, Max: 0.0020	0/1/2, Avg: 0.0065, Max: 0.013	0/1/3, Avg: 0.0017, Max: 0.0050	0/2/3, Avg: 0.0016, Max: 0.0037
Groundwater	ECO SLs REG 5 x 10	Cadmium	0.0015	1/1/2, Avg: 0.28, Max: 0.56	2/2/2, Avg: 0.016, Max: 0.026	2/2/7, Avg: 0.0060, Max: 0.037	4/4/8, Avg: 0.0046, Max: 0.019	9/9/10, Avg: 0.24, Max: 2.2	3/3/5, Avg: 0.013, Max: 0.051
Groundwater	ECO SLs REG 5 x 10	Calcium			0/2/2, Avg: 267, Max: 274	0/5/5, Avg: 266, Max: 461	0/3/3, Avg: 424, Max: 655	0/5/5, Avg: 616, Max: 654	0/2/3, Avg: 379, Max: 706
Groundwater	ECO SLs REG 5 x 10	Chromium	0.42	0/0/2, Avg: 0.0, Max: 0.0	0/1/2, Avg: 0.0039, Max: 0.0077	0/3/8, Avg: 0.0095, Max: 0.057	0/2/7, Avg: 0.059, Max: 0.25	0/4/8, Avg: 0.027, Max: 0.12	0/3/5, Avg: 0.033, Max: 0.079
Groundwater	ECO SLs REG 5 x 10	Cobalt	0.24		0/2/2, Avg: 0.018, Max: 0.022	0/3/4, Avg: 0.022, Max: 0.047	0/1/2, Avg: 0.036, Max: 0.071	0/4/4, Avg: 0.028, Max: 0.074	0/3/3, Avg: 0.047, Max: 0.10
Groundwater	ECO SLs REG 5 x 10	Copper	0.016		1/1/2, Avg: 0.047, Max: 0.094	3/5/5, Avg: 0.046, Max: 0.10	1/1/2, Avg: 0.13, Max: 0.25	2/2/4, Avg: 0.10, Max: 0.39	2/3/3, Avg: 1.0, Max: 3.1
Groundwater	ECO SLs REG 5 x 10	Iron		0/2/2, Avg: 11.4, Max: 17.3	0/2/2, Avg: 5.9, Max: 11.2	0/4/7, Avg: 7.1, Max: 33.8	0/4/5, Avg: 44.4, Max: 208	0/8/8, Avg: 13.1, Max: 84.6	0/4/4, Avg: 38.2, Max: 137
Groundwater	ECO SLs REG 5 x 10	Lead	0.012	0/1/2, Avg: 0.0055, Max: 0.011	2/2/2, Avg: 1.2, Max: 2.2	2/8/9, Avg: 0.078, Max: 0.61	3/6/10, Avg: 0.014, Max: 0.067	4/6/10, Avg: 0.081, Max: 0.61	3/3/5, Avg: 0.087, Max: 0.30
Groundwater	ECO SLs REG 5 x 10	Magnesium			0/2/2, Avg: 135, Max: 138	0/5/5, Avg: 110, Max: 119	0/3/3, Avg: 159, Max: 195	0/5/5, Avg: 70.1, Max: 120	0/3/3, Avg: 109, Max: 140
Groundwater	ECO SLs REG 5 x 10	Manganese		0/2/2, Avg: 6.8, Max: 11.5	0/2/2, Avg: 3.2, Max: 3.2	0/8/8, Avg: 4.6, Max: 20.7	0/6/6, Avg: 8.0, Max: 25.3	0/8/8, Avg: 7.5, Max: 12.4	0/4/4, Avg: 5.9, Max: 16.9
Groundwater	ECO SLs REG 5 x 10	Mercury	0.000013	1/1/2, Avg: 0.00012, Max: 0.00024	1/1/2, Avg: 0.0065, Max: 0.013	2/2/7, Avg: 0.00030, Max: 0.0016	0/0/7, Avg: 0.0, Max: 0.0	1/1/8, Avg: 0.000031, Max: 0.00025	1/1/5, Avg: 0.00042, Max: 0.0021
Groundwater	ECO SLs REG 5 x 10	Nickel	0.29	1/2/2, Avg: 0.29, Max: 0.49	0/2/2, Avg: 0.026, Max: 0.038	0/6/8, Avg: 0.026, Max: 0.075	0/5/6, Avg: 0.052, Max: 0.21	1/8/8, Avg: 0.18, Max: 1.1	0/4/4, Avg: 0.072, Max: 0.21
Groundwater	ECO SLs REG 5 x 10	Potassium			0/2/2, Avg: 77.3, Max: 77.3	0/5/5, Avg: 14.8, Max: 33.8	0/3/3, Avg: 17.0, Max: 46.1	0/5/5, Avg: 99.0, Max: 133	0/2/2, Avg: 58.2, Max: 108
Groundwater	ECO SLs REG 5 x 10	Selenium	0.050		0/0/1, Avg: 0.0, Max: 0.0	0/0/4, Avg: 0.0, Max: 0.0	0/0/6, Avg: 0.0, Max: 0.0	0/1/5, Avg: 0.00040, Max: 0.0020	0/1/3, Avg: 0.00067, Max: 0.0020
Groundwater	ECO SLs REG 5 x 10	Silver	0.0012		0/0/1, Avg: 0.0, Max: 0.0	0/0/4, Avg: 0.0, Max: 0.0	1/1/3, Avg: 0.011, Max: 0.033	2/2/5, Avg: 0.015, Max: 0.055	1/1/3, Avg: 0.013, Max: 0.038
Groundwater	ECO SLs REG 5 x 10	Sodium			0/2/2, Avg: 152, Max: 153	0/4/4, Avg: 178, Max: 278	0/3/3, Avg: 750, Max: 2000	0/5/5, Avg: 118, Max: 215	0/3/3, Avg: 157, Max: 228
Groundwater	ECO SLs REG 5 x 10	Thallium	0.10		0/0/1, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/1/3, Avg: 0.00043, Max: 0.0013
Groundwater	ECO SLs REG 5 x 10	Vanadium	0.12		0/1/2, Avg: 0.0075, Max: 0.015	0/1/3, Avg: 0.021, Max: 0.062	1/1/2, Avg: 0.13, Max: 0.25	0/3/4, Avg: 0.010, Max: 0.019	1/1/3, Avg: 0.053, Max: 0.16
Groundwater	ECO SLs REG 5 x 10	Zinc	0.66	2/2/2, Avg: 195, Max: 382	1/2/2, Avg: 1.7, Max: 3.3	3/8/8, Avg: 1.1, Max: 3.3	3/6/6, Avg: 1.7, Max: 5.3	8/8/8, Avg: 112, Max: 831	3/4/4, Avg: 7.5, Max: 26.4
Groundwater	PRG TAPWATER REG 9	Aluminum	36.0		0/1/2, Avg: 3.2, Max: 6.3	1/2/4, Avg: 12.3, Max: 48.3	1/1/2, Avg: 61.5, Max: 123	1/3/4, Avg: 14.8, Max: 55.0	0/3/4, Avg: 10.0, Max: 25.8
Groundwater	PRG TAPWATER REG 9	Antimony	0.015		0/0/1, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	1/1/2, Avg: 0.041, Max: 0.081
Groundwater	PRG TAPWATER REG 9	Arsenic	0.000045		2/2/2, Avg: 0.0041, Max: 0.0055	5/5/6, Avg: 0.0048, Max: 0.021	6/6/8, Avg: 0.0030, Max: 0.0071	7/7/7, Avg: 0.0060, Max: 0.0090	4/4/4, Avg: 0.013, Max: 0.022
Groundwater	PRG TAPWATER REG 9	Barium	2.6	0/2/2, Avg: 0.020, Max: 0.025	0/2/2, Avg: 0.089, Max: 0.13	0/8/9, Avg: 0.067, Max: 0.36	0/10/10, Avg: 0.52, Max: 2.5	0/10/10, Avg: 0.13, Max: 0.38	0/5/5, Avg: 0.36, Max: 1.1
Groundwater	PRG TAPWATER REG 9	Beryllium	0.073		0/0/1, Avg: 0.0, Max: 0.0	0/1/3, Avg: 0.00067, Max: 0.0020	0/1/2, Avg: 0.0065, Max: 0.013	0/1/3, Avg: 0.0017, Max: 0.0050	0/2/3, Avg: 0.0016, Max: 0.0037
Groundwater	PRG TAPWATER REG 9	Cadmium	0.018	1/1/2, Avg: 0.28, Max: 0.56	1/2/2, Avg: 0.016, Max: 0.026	1/2/7, Avg: 0.0060, Max: 0.037	1/4/8, Avg: 0.0046, Max: 0.019	5/9/10, Avg: 0.24, Max: 2.2	1/3/5, Avg: 0.013, Max: 0.051
Groundwater	PRG TAPWATER REG 9	Calcium			0/2/2, Avg: 267, Max: 274	0/5/5, Avg: 266, Max: 461	0/3/3, Avg: 424, Max: 655	0/5/5, Avg: 616, Max: 654	0/2/3, Avg: 379, Max: 706
Groundwater	PRG TAPWATER REG 9	Chromium	0.11	0/0/2, Avg: 0.0, Max: 0.0	0/1/2, Avg: 0.0039, Max: 0.0077	0/3/8, Avg: 0.0095, Max: 0.057	2/2/7, Avg: 0.059, Max: 0.25	1/4/8, Avg: 0.027, Max: 0.12	0/3/5, Avg: 0.033, Max: 0.079
Groundwater	PRG TAPWATER REG 9	Cobalt	0.73		0/2/2, Avg: 0.018, Max: 0.022	0/3/4, Avg: 0.022, Max: 0.047	0/1/2, Avg: 0.036, Max: 0.071	0/4/4, Avg: 0.028, Max: 0.074	0/3/3, Avg: 0.047, Max: 0.10
Groundwater	PRG TAPWATER REG 9	Copper	1.5		0/1/2, Avg: 0.047, Max: 0.094	0/5/5, Avg: 0.046, Max: 0.10	0/1/2, Avg: 0.13, Max: 0.25	0/2/4, Avg: 0.10, Max: 0.39	1/3/3, Avg: 1.0, Max: 3.1
Groundwater	PRG TAPWATER REG 9	Iron	11.0	1/2/2, Avg: 11.4, Max: 17.3	1/2/2, Avg: 5.9, Max: 11.2	2/4/7, Avg: 7.1, Max: 33.8	2/4/5, Avg: 44.4, Max: 208	1/8/8, Avg: 13.1, Max: 84.6	1/4/4, Avg: 38.2, Max: 137
Groundwater	PRG TAPWATER REG 9	Lead	0.015	0/1/2, Avg: 0.0055, Max: 0.011	2/2/2, Avg: 1.2, Max: 2.2	2/8/9, Avg: 0.078, Max: 0.61	3/6/10, Avg: 0.014, Max: 0.067	4/6/10, Avg: 0.081, Max: 0.61	3/3/5, Avg: 0.087, Max: 0.30
Groundwater	PRG TAPWATER REG 9	Magnesium			0/2/2, Avg: 135, Max: 138	0/5/5, Avg: 110, Max: 119	0/3/3, Avg: 159, Max: 195	0/5/5, Avg: 70.1, Max: 120	0/3/3, Avg: 109, Max: 140
Groundwater	PRG TAPWATER REG 9	Manganese	0.88	2/2/2, Avg: 6.8, Max: 11.5	2/2/2, Avg: 3.2, Max: 3.2	5/8/8, Avg: 4.6, Max: 20.7	4/6/6, Avg: 8.0, Max: 25.3	8/8/8, Avg: 7.5, Max: 12.4	3/4/4, Avg: 5.9, Max: 16.9
Groundwater	PRG TAPWATER REG 9	Mercury		0/1/2, Avg: 0.00012, Max: 0.00024	0/1/2, Avg: 0.0065, Max: 0.013	0/2/7, Avg: 0.00030, Max: 0.0016	0/0/7, Avg: 0.0, Max: 0.0	0/1/8, Avg: 0.000031, Max: 0.00025	0/1/5, Avg: 0.00042, Max: 0.0021
Groundwater	PRG TAPWATER REG 9	Nickel	0.73	0/2/2, Avg: 0.29, Max: 0.49	0/2/2, Avg: 0.026, Max: 0.038	0/6/8, Avg: 0.026, Max: 0.075	0/5/6, Avg: 0.052, Max: 0.21	1/8/8, Avg: 0.18, Max: 1.1	0/4/4, Avg: 0.072, Max: 0.21
Groundwater	PRG TAPWATER REG 9	Potassium			0/2/2, Avg: 77.3, Max: 77.3	0/5/5, Avg: 14.8, Max: 33.8	0/3/3, Avg: 17.0, Max: 46.1	0/5/5, Avg: 99.0, Max: 133	0/2/2, Avg: 58.2, Max: 108
Groundwater	PRG TAPWATER REG 9	Selenium	0.18		0/0/1, Avg: 0.0, Max: 0.0	0/0/4, Avg: 0.0, Max: 0.0	0/0/6, Avg: 0.0, Max: 0.0	0/1/5, Avg: 0.00040, Max: 0.0020	0/1/3, Avg: 0.00067, Max: 0.0020
Groundwater	PRG TAPWATER REG 9	Silver			0/0/1, Avg: 0.0, Max: 0.0	0/0/4, Avg: 0.0, Max: 0.0	0/1/3, Avg: 0.011, Max: 0.033	0/2/5, Avg: 0.015, Max: 0.055	0/1/3, Avg: 0.013, Max: 0.038
Groundwater	PRG TAPWATER REG 9	Sodium			0/2/2, Avg: 152, Max: 153	0/4/4, Avg: 178, Max: 278	0/3/3, Avg: 750, Max: 2000	0/5/5, Avg: 118, Max: 215	0/3/3, Avg: 157, Max: 228
Groundwater	PRG TAPWATER REG 9	Thallium			0/0/1, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/0/2, Avg: 0.0, Max: 0.0	0/0/3, Avg: 0.0, Max: 0.0	0/1/3, Avg: 0.00043, Max: 0.0013
Groundwater	PRG TAPWATER REG 9	Vanadium	0.036		0/1/2, Avg: 0.0075, Max: 0.015	1/1/3, Avg: 0.021, Max: 0.062	1/1/2, Avg: 0.13, Max: 0.25	0/3/4, Avg: 0.010, Max: 0.019	1/1/3, Avg: 0.053, Max: 0.16
Groundwater	PRG TAPWATER REG 9	Zinc	11.0	1/2/2, Avg: 195, Max: 382	0/2/2, Avg: 1.7, Max: 3.3	0/8/8, Avg: 1.1, Max: 3.3	0/6/6, Avg: 1.7, Max: 5.3	2/8/8, Avg: 112, Max: 831	1/4/4, Avg: 7.5, Max: 26.4

Rank	Description
-	Data not available
0	Not Detected
1	Detected - No Standard (Unknown Risk)
2	Detected - Below Standard (Low Risk)
3	Exceeds Standard (Medium Risk)
4	Exceeds 5 x Standard (Higher Risk)

Ecological scenario priority metals:

High priority: silver, zinc. Selected for higher risk categorization that is dominant in slag or, in case of zinc, slag concentrations are dominant.
Medium priority: cadmium, copper, lead, mercury, nickel. Selected for higher risk category metals that are consistent across submedia or for medium risk category metals in slag.

Human health scenario priority metals (focus on alluvial data or, in absence of alluvial data, slag data):

High priority: cadmium, zinc. Selected if higher risk in alluvial (slag) data, and alluvial (slag) risk categorizations exceed those of other media.
Medium priority: aluminum, arsenic, iron, manganese. Selected if medium risk in alluvial (slag) data or for higher risk category that is consistent across submedia.

Note:

- All units are mg/L.
- Summary values are (number of exceedances)/(number of detections)/(number of data records), arithmetic average, maximum.

Table 2c. Sediment Screening and Priority Metals Determination
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample Matrix	Criterion	Parameter	Standard	Sediment
Sediment	ECO SLs REG 5	Aluminum		0/9/13, Avg: 4930, Max: 20000
Sediment	ECO SLs REG 5	Antimony		0/4/8, Avg: 20.2, Max: 58.4
Sediment	ECO SLs REG 5	Arsenic	9.8	3/9/13, Avg: 9.6, Max: 37.7
Sediment	ECO SLs REG 5	Barium		0/14/20, Avg: 1090, Max: 7310
Sediment	ECO SLs REG 5	Beryllium		0/10/13, Avg: 0.74, Max: 2.3
Sediment	ECO SLs REG 5	Cadmium	0.99	19/19/20, Avg: 11.6, Max: 46.5
Sediment	ECO SLs REG 5	Calcium		0/8/13, Avg: 57300, Max: 243000
Sediment	ECO SLs REG 5	Chromium	43.4	5/18/20, Avg: 62.7, Max: 280
Sediment	ECO SLs REG 5	Cobalt	50.0	0/8/13, Avg: 7.3, Max: 18.6
Sediment	ECO SLs REG 5	Copper	31.6	9/11/13, Avg: 108, Max: 383
Sediment	ECO SLs REG 5	Iron		0/15/20, Avg: 33300, Max: 193000
Sediment	ECO SLs REG 5	Lead	35.8	15/19/20, Avg: 234, Max: 1050
Sediment	ECO SLs REG 5	Magnesium		0/8/8, Avg: 17100, Max: 34600
Sediment	ECO SLs REG 5	Manganese		0/15/20, Avg: 21700, Max: 155000
Sediment	ECO SLs REG 5	Mercury	0.17	12/14/20, Avg: 0.41, Max: 1.9
Sediment	ECO SLs REG 5	Nickel	22.7	11/19/20, Avg: 115, Max: 737
Sediment	ECO SLs REG 5	Potassium		0/11/13, Avg: 1540, Max: 6570
Sediment	ECO SLs REG 5	Selenium		0/2/13, Avg: 0.085, Max: 0.69
Sediment	ECO SLs REG 5	Silver	0.50	0/0/13, Avg: 0.0, Max: 0.0
Sediment	ECO SLs REG 5	Sodium		0/8/13, Avg: 532, Max: 3960
Sediment	ECO SLs REG 5	Thallium		0/2/13, Avg: 0.052, Max: 0.38
Sediment	ECO SLs REG 5	Vanadium		0/10/13, Avg: 28.3, Max: 68.8
Sediment	ECO SLs REG 5	Zinc	121	18/20/20, Avg: 2350, Max: 12100

Rank	Description
-	Data not available
0	Not Detected
1	Detected - No Standard (Unknown Risk)
2	Detected - Below Standard (Low Risk)
3	Exceeds Standard (Medium Risk)
4	Exceeds 5 x Standard (Higher Risk)

Ecological scenario priority metals:
High priority: cadmium, chromium, copper, lead, mercury, nickel, zinc. Selected if higher risk in sediment.
Medium priority: arsenic. Selected if medium risk in sediment.

Note:

1. All units are mg/kg.
2. Summary values are (number of exceedances)/(number of detections)/(number of data records), arithmetic average, maximum.

Table 2d. Surface-Water Screening and Priority Metals Determination
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample Matrix	Criterion	Parameter	Standard	Surface Water
Surface Water	ECO SLs REG 5	Barium	0.22	0/3/3, Avg: 0.11, Max: 0.12
Surface Water	ECO SLs REG 5	Cadmium	0.00015	0/0/3, Avg: 0.0, Max: 0.0
Surface Water	ECO SLs REG 5	Chromium	0.042	0/0/3, Avg: 0.0, Max: 0.0
Surface Water	ECO SLs REG 5	Iron		0/3/3, Avg: 2.2, Max: 3.2
Surface Water	ECO SLs REG 5	Lead	0.0012	3/3/3, Avg: 0.0041, Max: 0.0076
Surface Water	ECO SLs REG 5	Manganese		0/3/3, Avg: 0.50, Max: 1.2
Surface Water	ECO SLs REG 5	Mercury	0.0000013	2/2/3, Avg: 0.00014, Max: 0.00022
Surface Water	ECO SLs REG 5	Nickel	0.029	0/0/3, Avg: 0.0, Max: 0.0
Surface Water	ECO SLs REG 5	Zinc	0.066	2/3/3, Avg: 0.071, Max: 0.096

Rank	Description
-	Data not available
0	Not Detected
1	Detected - No Standard (Unknown Risk)
2	Detected - Below Standard (Low Risk)
3	Exceeds Standard (Medium Risk)
4	Exceeds 5 x Standard (Higher Risk)

Ecological scenario priority metals:

High priority: lead, mercury. Selected if higher risk in surface water.

Medium priority: zinc. Selected if medium risk in surface water.

Note:

1. All units are mg/L.
2. Summary values are (number of exceedances)/(number of detections)/(number of data records), arithmetic average, maximum.

Table 3. Media Screening Summary and Priority Metals Determination
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Parameter	Soil		Groundwater		Sediment	Surface Water
	PRG INDUSTRIAL REG 9	ECO SLs REG 5	PRG TAPWATER REG 9	ECO SLs REG 5	ECO SLs REG 5	ECO SLs REG 5
Aluminum	Low	Low	Medium	Low	Low	Low
Antimony	Low	High	Low	Low	Low	Low
Arsenic	High	High	Medium	Low	Medium	Low
Barium	Low	Medium	Low	Low	Low	Low
Beryllium	Low	High	Low	Low	Low	Low
Cadmium	Low	Medium	High	Medium	High	Low
Calcium	Low	Low	Low	Low	Low	Low
Chromium	Medium	Medium	Low	Low	High	Low
Cobalt	Low	Medium	Low	Low	Low	Low
Copper	Low	Medium	Low	Medium	High	Low
Iron	Medium	Low	Medium	Low	Low	Low
Lead	High	Medium	Low	Medium	High	High
Magnesium	Low	Low	Low	Low	Low	Low
Manganese	High	Low	Medium	Low	Low	Low
Mercury	Low	High	Low	Medium	High	High
Nickel	Low	High	Low	Medium	High	Low
Potassium	Low	Low	Low	Low	Low	Low
Selenium	Low	High	Low	Low	Low	Low
Silver	Low	Medium	Low	High	Low	Low
Sodium	Low	Low	Low	Low	Low	Low
Thallium	Low	High	Low	Low	Low	Low
Vanadium	Low	Medium	Low	Low	Low	Low
Zinc	Low	High	High	High	High	Medium

Overall Metals Priority Ranking		
Parameter	Rank	Overall Priority Score
Zinc	1	15
Lead	2	14
Mercury	3	13
Arsenic	4	12
Cadmium	5	12
Nickel	6	11
Chromium	7	10
Copper	8	10
Manganese	9	9
Silver	10	9
Antimony	11	8
Beryllium	12	8
Iron	13	8
Selenium	14	8
Thallium	15	8
Aluminum	16	7
Barium	17	7
Cobalt	18	7
Vanadium	19	7
Calcium	20	6
Magnesium	21	6
Potassium	22	6
Sodium	23	6

Notes:

1. In the overall priority ranking, a metal receives in each risk scenario a score of 3 for high priority, 2 for medium priority, and 1 for low priority.

Table 4. Comparison of Groundwater Summary Statistics and P-1 Results
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Company Site, Operable Unit 1
LaSalle, Illinois

Parameter	Standard	Summary Statistics	1994 P-1 Data	Behavior Summary
Cadmium	0.018	10/21/34, Avg: 0.093, Max: 2.2	2.2	Most mobile at low pH
Chromium	0.11	3/13/32, Avg: 0.027, Max: 0.25	0.0066 B	Insensitive to pH
Iron	11	8/24/28, Avg: 20.1, Max: 208	1.5	Most mobile at low pH if in oxidizing conditions
Lead	0.015	14/26/38, Avg: 0.12, Max: 2.2	0.0050 U	Most mobile at low pH
Manganese	0.88	24/30/30, Avg: 6.3, Max: 25.3	12.4	Most mobile at low pH if in oxidizing conditions
Mercury	0.011	1/5/31, Avg: 0.00057, Max: 0.013	0.00025	Somewhat more mobile at low pH
Nickel	0.73	1/27/30, Avg: 0.095, Max: 1.1	1.1	Most mobile at low pH
Zinc	11	4/30/30, Avg: 44.6, Max: 831	831	Most mobile at low pH

**Table 5. Potential Federal and State ARARs and TBCs
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Company Site, Operable Unit 1
LaSalle, Illinois**

POTENTIAL ARAR		CITATION	BRIEF DESCRIPTION	ARAR/TBC STATUS
FEDERAL CHEMICAL-SPECIFIC ARARS				
<i>USEPA Region IX Preliminary Remediation Goals</i>		http://www.epa.gov/region9/waste/sfund/prg/index.html	Guidance concentrations used for screening soil and groundwater against human health endpoints.	TBC – May be used to help establish site-specific cleanup goals.
<i>USEPA Region IX Ecological Screening Values</i>		http://www.epa.gov/reg5rcra/ca/edql.htm	Guidance concentrations used for screening soil, sediment, and surface-water data against ecological endpoints.	TBC – May be used to help establish site-specific cleanup goals.
<i>USEPA Ecological Soil Screening Levels</i>		http://www.epa.gov/ecotox/ecoss/	Guidance concentrations used for screening soils data against ecological endpoints.	TBC – May be used to help establish site-specific cleanup goals.
<i>USEPA National Recommended Water Quality Criteria</i>		http://www.epa.gov/waterscience/criteria/wqcriteria.html	Guidance concentrations used for screening surface-water data against ecological endpoints.	TBC – May be used to help establish site-specific cleanup goals.
<i>Clean Water Act</i>	<i>Water Quality Standards</i>	40 CFR 131	Sets criteria for surface water quality for 95 carcinogenic and non-carcinogenic compounds based on toxicity to aquatic organisms and human health. Involves river listing and Total Maximum Daily Loads (TMDLs.)	TBC – To the discharge of wastewaters during remedy implementation.
	<i>Toxic Pollutant Effluent Standards</i>	40 CFR 129	Establishes effluent standards or prohibitions for certain toxic pollutants: pesticides or PCBs.	Potentially Applicable - If the selected remedy will result in the discharge of pesticides or PCBs.
<i>Safe Drinking Water Act</i>	<i>Maximum Contaminant Levels</i>	40 CFR 141	Establishes maximum allowable concentrations for drinking water.	TBC – May be used to help establish site-specific cleanup goals.
<i>Clean Air Act</i>	<i>National Ambient Air Quality Standards (NAAQS)</i>	40 CFR 50	Establishes emission limits for seven pollutants. Describes test methods and procedures to determine particulate emissions. Used for designating air quality in the U.S.	TBC – May apply to the onsite generation and emission of ambient air pollutants during implementation of the selected remedy.
<i>Toxic Substances Control Act</i>	<i>Polychlorinated Biphenyls Manufacturing, Process, Distribution in Commerce, and Use Prohibitions</i>	40 CFR 761	Provides cleanup methodology and standards for PCBs.	Potentially Applicable - If the selected remedy will require the management of PCBs.

**Table 5. Potential Federal and State ARARs and TBCs
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Company Site, Operable Unit 1
LaSalle, Illinois**

POTENTIAL ARAR		CITATION	BRIEF DESCRIPTION	ARAR/TBC STATUS
STATE CHEMICAL-SPECIFIC ARARS				
<i>Environmental Protection - Water Pollution</i>	<i>Water Quality Standards</i>	Title 35 IAC, Subtitle C, Chapter I, Parts 302 and 303	Establishes water quality criteria.	TBC - May be used to help establish site-specific cleanup goals.
<i>Environmental Protection - Air Pollution</i>	<i>Air Emissions Standards</i>	Title 35 IAC, Subtitle B, Chapter I, Parts 212 through 219; 232, 243, 245	Provide air emission standards for particulates, opacity, VOCs, sulfur compounds, air toxics, odor, etc.	Potentially Applicable - If the selected remedy will involve a treatment system or the movement of large quantities of solid materials (dust generation).
<i>Environmental Protection - Public Water Supplies</i>	<i>Maximum Contaminant Levels</i>	Title 35 IAC, Subtitle F, Chapter I, Part 611, Subparts F and G	Establishes maximum allowable concentrations for drinking water.	TBC - May be used to help establish site-specific cleanup goals.
<i>Environmental Protection - Public Water Supplies</i>	<i>Groundwater Quality</i>	Title 35 IAC, Subtitle F, Chapter I, Part 620	Defines groundwater classes and associated groundwater quality standards.	TBC - May be used to help establish site-specific cleanup goals.
FEDERAL LOCATION-SPECIFIC ARARS				
<i>Endangered Species Act</i>		16 USC 1531	Provides a means for the protection of flora and fauna.	Potentially Relevant and Appropriate - If the proposed remedy would affect these resources.
<i>Clean Water Act, Section 404</i>		33 USC 1344	Regulates dredge and fill activities, including wetlands.	Potentially Applicable - If implementation of the selected remedy would involve dredge and fill activities, including wetland impacts.
<i>Fish and Wildlife Coordination Act</i>		16 USC 661	Any activity that proposes to modify a body of water or potentially affect fish and wildlife services is addressed under CWA Section 404 requirements.	Potentially Relevant and Appropriate - If the proposed remedy would affect these resources.
<i>Comprehensive Environmental Response, Compensation, and Liability Act</i>	<i>National Oil and Hazardous Substances Pollution Contingency Plan</i>	40 CFR 300	Provides for Federal oversight and planning dealing with releases of hazardous substances and remedial actions.	Applicable - Defines the Federal-level decision-making process for NPL sites.

**Table 5. Potential Federal and State ARARs and TBCs
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Company Site, Operable Unit 1
LaSalle, Illinois**

POTENTIAL ARAR	CITATION	BRIEF DESCRIPTION	ARAR/TBC STATUS
FEDERAL ACTION-SPECIFIC ARARS			
<i>Hazardous Waste Management Act</i>	<i>Transportation</i>	49 CFR Parts 100-177	Regulates transportation of hazardous materials. Applicable – To the offsite transportation of hazardous materials and wastes.
<i>Hazardous Waste Management Act</i>	<i>Hazardous Waste Management Systems: General</i>	40 CFR 260	Establishes procedures and criteria for modification or revocation of any provision in 40 CFR Part 260-265, including the requirements for petitioning for the delisting of a particular hazardous waste stream. Potentially Applicable – If implementation of the RI/FS or the selected remedy results in the generation of hazardous waste.
<i>Resource Conservation and Recovery Act</i>	<i>Identification and Listing of Hazardous Waste</i>	40 CFR 261	Defines solid wastes that are subject to regulation as hazardous wastes under 40 CFR Parts 262-265 and Part 270. Applicable – All wastes must be profiled prior to disposal. If the remedial action results in the generation of hazardous waste (spoils, PPE, etc.) then additional requirements may apply.
<i>Resource Conservation and Recovery Act</i>	<i>Standards Applicable to Generators of Hazardous Waste</i>	40 CFR 262	Establishes standards for generators of hazardous waste. Potentially Applicable – If the RI/FS or the selected remedy results in the generation of hazardous waste.
<i>Resource Conservation and Recovery Act</i>	<i>Standards Applicable to Transporters of Hazardous Waste</i>	40 CFR 263	Establishes standards that apply to entities transporting hazardous waste within the U.S. Potentially Applicable – If the RI/FS or the selected remedy results in the offsite transportation of hazardous waste.
<i>Resource Conservation and Recovery Act</i>	<i>Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities</i>	40 CFR 264	Standards and requirements for facilities that treat, store, and dispose of hazardous waste. Requirements include: General Facility Standards (Subpart B), Preparedness and Prevention (Subpart C), Contingency Plan and Emergency Procedures (Subpart D), Man Potentially Applicable – To the management of hazardous waste, if generated. Potentially Appropriate and Relevant – If wastes will be stored onsite long-term, especially in a CAMU
<i>Resource Conservation and Recovery Act</i>	<i>Land Disposal Restrictions</i>	40 CFR 268	Identifies hazardous wastes that are restricted from land disposal and defines those limited circumstances under which an otherwise restricted waste may continue to be land disposed. Potentially Applicable – If the selected remedy results in the generation of hazardous waste that will be land-disposed.
<i>Clean Water Act</i>	<i>National Pollutant Discharge Elimination System (NPDES)</i>	33 USC Section 1342; 40 CFR 122 and 125	Covers permitting requirements for aqueous discharge into navigable waters Potentially Applicable – If the selected remedy will result in the discharge of water to navigable waters.

**Table 5. Potential Federal and State ARARs and TBCs
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Company Site, Operable Unit 1
LaSalle, Illinois**

POTENTIAL ARAR		CITATION	BRIEF DESCRIPTION	ARAR/TBC STATUS
<i>Toxic Substances Control Act</i>	<i>Polychlorinated Biphenyls Manufacturing, Process, Distribution in Commerce, and Use Prohibitions</i>	40 CFR 761	Provides cleanup methodology and standards for PCBs.	Applicable - If the selected remedy will involve the management and remediation of PCB-containing wastes.
<i>Occupational Safety and Health Act</i>	<i>Occupational Health and Safety Standards</i>	29 CFR 1910	Requirements for worker safety.	Applicable - To any portions of the remedial action not related to construction. Includes provisions for health and safety related to hazardous waste operations (40 CFR 1910.120)
<i>Occupational Safety and Health Act</i>	<i>Safety and Health Regulations for Construction</i>	29 CFR 1926	Requirements for worker safety during construction.	Applicable - To any remedial action involving construction.
STATE ACTION-SPECIFIC ARARS				
<i>Environmental Protection - Noise</i>	<i>Noise</i>	Title 35 IAC, Subtitle H, Chapter I, Parts 900 and 901	Establishes numeric criteria for noise emissions.	Potentially Applicable - If the selected remedy will entail noisy operations.
<i>Environmental Protection - Right to Know</i>	<i>Standards and Requirements for Potable Water Supply Well Surveys and for Community Relations Activities Performed in Conjunction with Agency Notices of Threats from Contamination</i>	Title 35 IAC, Subtitle O, Chapter I, Part 1600	Presents methodology for conducting potable well surveys and conveying contamination concerns to the community.	Applicable - If groundwater impacts are present.

Table 6. Sampling Information for Solid, Air, Surface-Water, Sediment, and Groundwater Sampling
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample ID	Matrix	Location	Depth or Stratum	TAL Metals	VOCs	SVOCs	Pesticides	PCBs	Cyanide	Asbestos	TAL Metals SPLP	Soil pH	SEP	ARD	AVS/SEM	IOC	Orthophosphate	Sulfate	Field Parameters		
																			Ferrous Iron	Sulfide	Alkalinity
OUI-SS-SB301-0-1	Slag/Soil	SB-301	0-1 ft BLS	x	x	x	x	x	x	x	x	x	x	x							
OUI-AA-SB301	Ambient Air		0-1 ft BLS							x											
OUI-SS-SB301-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB301-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB302-0-1	Slag/Soil	SB-302	0-1 ft BLS	x																	
OUI-AA-SB302	Ambient Air		0-1 ft BLS							x											
OUI-SS-SB302-D1-D2	Slag		5 ft Above Water Table	x	x	x			x		x	x	x	x							
OUI-SS-SB302-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB303-0-1	Slag/Soil	SB-303	0-1 ft BLS	x			x	x													
OUI-SS-SB303-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB303-D1-D2	Slag		5 ft Below Water Table	x	x	x			x		x	x	x	x							
OUI-SS-SB303-D1-D2	Soil		Alluvium	x							x	x	x								
OUI-SS-SB304-0-1	Slag/Soil	SB-304	0-1 ft BLS	x							x	x									
OUI-AA-SB304	Ambient Air		0-1 ft BLS							x											
OUI-SS-SB304-D1-D2	Slag		5 ft Above Water Table	x									x								
OUI-SS-SB304-D1-D2	Slag		5 ft Below Water Table	x	x	x			x												
OUI-SS-SB305-0-1	Slag/Soil	SB-305	0-1 ft BLS	x			x	x													
OUI-SS-SB305-D1-D2	Slag		5 ft Above Water Table	x							x	x									
OUI-SS-SB305-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB306-0-1	Slag/Soil	SB-306	0-1 ft BLS	x	x	x			x												
OUI-SS-SB306-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB306-D1-D2	Slag		5 ft Below Water Table	x							x	x									
OUI-SS-SB307-0-1	Slag/Soil	SB-307	0-1 ft BLS	x			x	x			x	x	x								
OUI-SS-SB307-D1-D2	Slag		5 ft Above Water Table	x	x	x			x												
OUI-SS-SB307-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB308-0-1	Slag/Soil	SB-308	0-1 ft BLS	x																	
OUI-SS-SB308-D1-D2	Slag		5 ft Above Water Table	x							x	x									
OUI-SS-SB308-D1-D2	Slag		5 ft Below Water Table	x	x	x			x												
OUI-SS-SB309-0-1	Slag/Soil	SB-309	0-1 ft BLS	x			x	x													
OUI-SS-SB309-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB309-D1-D2	Slag		5 ft Below Water Table	x							x	x									
OUI-SS-SB309-D1-D2	Soil		Alluvium	x	x	x			x		x	x									
OUI-SS-SB310-0-1	Slag/Soil	SB-310	0-1 ft BLS	x							x	x									
OUI-SS-SB310-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB310-D1-D2	Slag		5 ft Below Water Table	x	x	x			x												
OUI-SS-SB311-0-1	Soil	SB-311	0-1 ft BLS	x	x	x	x	x	x				x	x							
OUI-SS-SB311-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB312-0-1	Soil	SB-312	0-1 ft BLS	x																	
OUI-SS-SB312-2-4	Soil		2-4 ft BLS	x	x	x	x	x	x												
OUI-SS-SB313-0-1	Soil	SB-313	0-1 ft BLS	x																	
OUI-SS-SB313-2-4	Soil		2-4 ft BLS	x									x	x							
OUI-SS-SB314-0-1	Soil	SB-314	0-1 ft BLS	x																	
OUI-SS-SB314-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB315-0-1	Soil	SB-315	0-1 ft BLS	x	x	x	x	x	x												
OUI-SS-SB315-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB316-0-1	Soil	SB-316	0-1 ft BLS	x									x								
OUI-SS-SB316-2-4	Soil		2-4 ft BLS	x	x	x	x	x	x												
OUI-SS-SB317-0-1	Soil	SB-317	0-1 ft BLS	x																	
OUI-SS-SB317-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB318-0-1	Soil	SB-318	0-1 ft BLS	x																	
OUI-SS-SB318-2-4	Soil		2-4 ft BLS	x									x	x							
OUI-SS-SB319-0-1	Soil	SB-319	0-1 ft BLS	x	x	x	x	x	x												
OUI-SS-SB319-2-4	Soil		2-4 ft BLS	x																	
OUI-SE-LVR201-yyymmdd	Sediment	LVR-201	0-6" Into Sediment	x	x	x	x	x	x						x						
OUI-SW-LVR201-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR202-yyymmdd	Sediment	LVR-202	0-6" Into Sediment	x																	
OUI-SE-LVR203-yyymmdd	Sediment		0-6" Into Sediment	x											x						
OUI-SW-LVR203-yyymmdd	Surface Water	LVR-203	Middle of Column	x																	
OUI-SF-LVR204-yyymmdd	Sediment		0-6" Into Sediment	x																	
OUI-SE-LVR205-yyymmdd	Sediment	LVR-205	0-6" Into Sediment	x	x	x	x	x	x						x						
OUI-SW-LVR205-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR206-yyymmdd	Sediment	LVR-206	0-6" Into Sediment	x			x														

Table 6. Sampling Information for Solid, Air, Surface-Water, Sediment, and Groundwater Sampling
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample ID	Matrix	Location	Depth or Stratum	TAL Metals	VOCs	SVOCs	Pesticides	PCBs	Cyanide	Asbestos	TAL Metals SPLP	Soil pH	SEP	XRD	AVS/SEM	TOC	Orthophosphate	Sulfate	Field Parameters		
																			Ferrous Iron	Sulfide	Alkalinity
OUI-SE-LVR207-yyymmdd	Sediment	LVR-207	0-6" Into Sediment	x			x								x						
OUI-SW-LVR207-yyymmdd	Surface Water		Middle of Column	x			x														
OUI-SE-LVR208-yyymmdd	Sediment	LVR-208	0-6" Into Sediment	x			x														
OUI-SE-LVR209-yyymmdd	Sediment	LVR-209	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR209-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR210-yyymmdd	Sediment	LVR-210	0-6" Into Sediment	x																	
OUI-SE-LVR211-yyymmdd	Sediment	LVR-211	0-6" Into Sediment	x																	
OUI-SW-LVR211-yyymmdd	Surface Water		Middle of Column	x																	
OUI-SE-LVR212-yyymmdd	Sediment	LVR-212	0-6" Into Sediment	x																	
OUI-SE-LVR213-yyymmdd	Sediment	LVR-213	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR213-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR214-yyymmdd	Sediment	LVR-214	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR214-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-UL215-yyymmdd	Sediment	UL-215	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-UL215-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-GW-MW-2-yyymm	Groundwater	MW-2	Alluvium	x	x	x			x							x	x	x	x	x	x
OUI-GW-MW-301H-yyymm	Groundwater	MW-301H	Alluvium	x															x	x	x
OUI-GW-MW-303H-yyymm	Groundwater	MW-303H	Alluvium	x															x	x	x
OUI-GW-MW-305H-yyymm	Groundwater	MW-305H	Alluvium	x															x	x	x
OUI-GW-MW-310H-yyymm	Groundwater	MW-310H	Alluvium	x	x	x			x							x	x	x	x	x	x
OUI-GW-P-17-yyymm	Groundwater	P-17	Alluvium	x															x	x	x
OUI-GW-P-18-yyymm	Groundwater	P-18	Alluvium	x															x	x	x
OUI-GW-G-02-yyymm	Groundwater	G-02	Bedrock	x												x	x	x	x	x	x
OUI-GW-G-101-yyymm	Groundwater	G-101	Bedrock	x	x	x			x										x	x	x
OUI-GW-MW-305R-yyymm	Groundwater	MW-305R	Bedrock	x															x	x	x
OUI-GW-MW-311R-yyymm	Groundwater	MW-311R	Bedrock	x												x	x	x	x	x	x
OUI-GW-MW-317R-yyymm	Groundwater	MW-317R	Bedrock	x												x	x	x	x	x	x
OUI-GW-P-15-yyymm	Groundwater	P-15	Bedrock	x	x	x			x										x	x	x
OUI-GW-P-7-yyymm	Groundwater	P-7	Bedrock	x															x	x	x
OUI-GW-P-9-yyymm	Groundwater	P-9	Bedrock	x												x	x	x	x	x	x
OUI-GW-G-05-yyymm	Groundwater	G-05	Fill	x												x	x	x	x	x	x
OUI-GW-P-20-yyymm	Groundwater	P-20	Fill	x	x	x			x							x	x	x	x	x	x
OUI-GW-G-106-yyymm	Groundwater	G-106	Slag	x												x	x	x	x	x	x
OUI-GW-MW-1-yyymm	Groundwater	MW-1	Slag	x															x	x	x
OUI-GW-MW-301S-yyymm	Groundwater	MW-301S	Slag	x															x	x	x
OUI-GW-MW-303S-yyymm	Groundwater	MW-303S	Slag	x	x	x			x										x	x	x
OUI-GW-MW-304S-yyymm	Groundwater	MW-304S	Slag	x															x	x	x
OUI-GW-MW-305S-yyymm	Groundwater	MW-305S	Slag	x												x	x	x	x	x	x
OUI-GW-MW-306S-yyymm	Groundwater	MW-306S	Slag	x															x	x	x
OUI-GW-P-1-yyymm	Groundwater	P-1	Slag	x	x	x			x										x	x	x
OUI-GW-P-15A-yyymm	Groundwater	P-15A	Slag	x															x	x	x
OUI-GW-P-19-yyymm	Groundwater	P-19	Slag	x															x	x	x
OUI-GW-G-04-yyymm	Groundwater	G-04	Till	x												x	x	x	x	x	x
OUI-GW-G-103-yyymm	Groundwater	G-103	Till	x	x	x			x										x	x	x
OUI-GW-P-6-yyymm	Groundwater	P-6	Till	x												x	x	x	x	x	x

- Notes:
1. ID: Identification
 2. TAL: Target Analyte List
 3. VOC: Volatile Organic Compound
 4. SVOC: Semi-Volatile Organic Compound
 5. PCB: Polychlorinated Biphenyl
 6. SPLP: Synthetic Precipitation Leaching Procedure
 7. SEP: Sequential Extraction Procedure
 8. XRD: X-Ray Diffraction
 9. AVS/SEM: Acid Volatile Sulfide/Simultaneously Extracted Metals
 10. TOC: Total Organic Carbon
 11. TBD: To Be Determined
 12. 0 BLS: feet below land surface
 13. OUI: Operable Unit 1
 14. SW: Surface Water
 15. SE: Sediment
 16. SS: Solid Matrix
 17. SB: Soil Boring
 18. LVR: Little Vermilion River
 19. UL: Upland
 20. Where "Slag/Soil" is indicated in matrix column, the actual matrix encountered will be noted during sampling.

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_CFM

Description: Chemistry Field Measurement

Field Name (PK) Primary Key	Description	Type	Length
loc_vs_site	Enter "Location" if the measured parameter pertains to a single location, such as a measurement taken at a well. Enter "Site" if the measured parameter pertains to the site as a whole, such as air temperature.	Text	35
sys_code	If parameter applies to specific sample location, enter the sys_loc_code. The sys_loc_code must be valid code for the facility. If the parameter applies to the site as a whole, enter a site_code, such as 01, found in field 1 of the SITE table.	Text	20
param_code	Parameter being measured. Use values from Table A-13 in the Appendix. The values in Table A-13 were derived from Chemical Abstracts Registry (CAS) Number, if available. Otherwise from the USAF ERPIMS PARLABEL.	Text	10
measurement_date	Date of measurement in MM/DD/YYYY format	Date/Time	8
measurement_time	Time of sample collection in 24-hr (military) HH:MM format. Default to 00:00 if unknown	Date/Time	8
param_value	Measured value.	Text	20
param_unit	Units that correspond to param_value. See Table A-18 in the Appendix for a list of valid values.	Text	15
measurement_method	Method used to collect the measurement.	Text	20
param_value_background	Background value of measured parameter.	Text	20
remark	Any comment or information, such as measurement detection limit, as needed.	Text	255
subcontractor_name_code	Name of contracting company responsible for field measurements.	Text	10
worker_name	Name of individual that took the measurement.	Text	50
instrument_id	Identifier for instrument used to take measurement.	Text	50
calibration_date	Date that instrument was last MM/DD/YYYY	Date/Time	8

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_EIW

Description: Extraction / Injection Well Table

Field Name (PK)	Primary Key	Description	Type	Length
sys_loc_code		Location ID	Text	20
sys_well_code		Location ID if multiple wells in one location	Text	255
start_measurement_date		Date MM/DD/YYYY	Date/Time	8
start_measurement_time		Time 00:00	Date/Time	8
end_measurement_date		Date MM/DD/YYYY	Date/Time	8
end_measurement_time		Time 00:00	Date/Time	8
avg_pump_rate			Double	8
pump_rate_unit			Text	15
pct_operating_time			Text	3
operating_mode			Text	14
design_rate			Text	14
design_rate_unit			Text	14
rate_measurement_type			Text	10
suction			Text	14
remark			Text	255

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_GWTR

Description: Groundwater Levels

Field Name (PK) Primary Key	Description	Type	Length
(PK) sys_loc_code	Location ID	Text	20
(PK) sys_well_code	Location ID if multiple wells in one location	Text	255
(PK) measurement_date	Date MM/DD/YYYY of groundwater level measurement	Date/Time	8
(PK) measurement_time	Time 00:00 of groundwater level measurement	Date/Time	8
historical_ref_elev	Elevation of the reference point from which the groundwater level was measured (typical top of casing)	Double	8
(PK) water_level_depth		Single	4
water_level_elev		Single	4
corrected_depth	Depth of water level after any corrections, for example if free product was encountered	Single	4
corrected_elev		Single	4
measured_depth_of_well		Single	4
depth_unit		Text	15
technician		Text	30
dry_indicator_yn	Is well dry? "Y" or "N"	Text	1
measurement_method		Text	20
batch_number		Text	10
dip_or_elevation		Text	10
remark		Text	255

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_LOC

Description: Locations

Field Name (PK) Primary Key	Description	Type	Length
(PK) sys_loc_code	Location ID, such as MW-01, A24, SW12, or SB-2S, for all samples collected, including groundwater samples, hydropunch samples, surface water/sediment samples, and soil samples.	Text	20
sys_well_code	Code used to differentiate between multiple wells installed at the same location. If one well exists, use sys_loc_code field. For surface water samples use "Surface". For all soil and other samples not associated with a well, insert "None."	Text	20
X_coord	Sampling location numeric x coordinate in UTM NAD83 meters coordinate system.	Double	8
Y_coord	Sampling location numeric y coordinate in UTM NAD83 meters coordinate system.	Double	8
surf_elev	Elevation of the ground surface, or if location is for surface water samples, water surface elevation. For water surface elevation, use the average annual elevation.	Double	8
elev_unit	Unit of measurement for elevations. Note: At this time, units must be feet.	Text	15
coord_sys_desc	Sampling location coordinate system description. Must be UTM followed by appropriate zone number, e.g., UTM zone 16.	Text	20
observation_date	Date observation or site survey was made.	Date/Time	8
alt_x_coord	Longitude of sampling location in decimal degrees.	Text	20
alt_y_coord	Latitude of sampling location in decimal degrees.	Text	20
coord_type_code	Code for the coordinate type used for alt_x and alt_y. In all cases this will be "Lat Long."	Text	20
identifier	This field is only to be used by EPA Region 5 personnel. Please leave blank.	Text	1
horiz_collect_method_code	Method used to determine the latitude/longitude. Use codes in Appendix Table A-3, Horizontal Collection Method.	Text	2
horiz_accuracy_value	Accuracy range (+/-) of the latitude and longitude. Only the least accurate measurement should be reported, regardless if it is for latitude or longitude.	Text	20
horiz_accuracy_unit	Unit of the horizontal accuracy value. Use values in Table A-4 of the Appendix.	Text	1
horiz_datum_code	Reference datum of the latitude and longitude. Use codes in Table A-5 of the Appendix.	Text	1
elev_collect_method_code	Method used to determine the ground elevation of the sampling location. Use codes in Table A-6 of the Appendix.	Text	2
elev_accuracy_value	Accuracy range (+/-) of the elevation measurement.	Text	20
elev_accuracy_unit	Unit of the elevation accuracy value. Use values in Table A-18 of the Appendix.	Text	15
elev_datum_code	Reference datum for the elevation measurement. Must use valid value from Table A-7 of the Appendix 7.7	Text	1
source_scale	Scale of source used to determine the latitude and longitude. Must be a valid code from Table A-8 of the Appendix. If GPS is used, this field does not apply and "N" should be entered.	Text	2
subcontractor_name_code	Code used to distinguish subcontractor name.	Text	20

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

verification_code	This field is only to be used by EPA Region 5 personnel. Please leave blank.	Text	1
reference_point	Describes the place at which coordinates were established. Use codes from Table A-2 in the Appendix.	Text	50
geometric_type_code	This field is for by EPA Region 5 future use. Please leave blank.	Text	20
rank	This field is for by EPA Region 5 future use. Please leave blank.	Long Integer	4
loc_name	Sampling location name.	Text	40
loc_desc	Sampling location description.	Text	255
loc_type	Description of sampling type, such as direct push, extraction well, or sediment. Use codes from Table A-9 in the Appendix.	Text	10
loc_purpose	Sampling location purpose.	Text	20
primary_site_code	Unique code for site or area. Must match site_code field from Table 3-1: Site File Data Structure.	Text	3
within_facility_yn	Indicates whether this sampling location is within facility boundaries, "Y" for yes or "N" for no.	Text	1
loc_county_code	Location county code; controlled vocabulary using FIPS (Federal Information Processing Standard) codes. FIPS codes can be found via the internet at http://www.itl.nist.gov/fipspubs/ or http://www.oseda.missouri.edu/jgb/geos.html	Text	20
loc_district_code	Location district code; controlled vocabulary using FIPS codes.	Text	20
loc_state_code	Location state code; controlled vocabulary using FIPS codes.	Text	10
loc_major_basin	Location major basin; controlled vocabulary using HUC (hydrologic unit codes). Use values listed in Table A-21 in the Appendix.	Text	20
loc_minor_basin	Location minor basin; controlled vocabulary using HUC codes. Any digits after the 8th (first 8 are reported in loc_major_basin) should be reported here.	Text	20
remark	Location specific comment.	Text	255
total_depth	• Total depth below ground surface of boring, in feet.	Double	8
depth_to_bedrock	Depth below ground surface of bedrock in feet.	Double	8
depth_to_top_of_screen	Depth in feet below ground surface to the top of the well screen. This information is required to obtain the vertical location from which the groundwater sample was taken. Leave null if well is not at this location.	Double	8
depth_to_bottom_of_screen	Depth in feet below ground surface to the bottom of the well screen. This information is required to obtain the vertical location from which the groundwater sample was taken. Leave null if well is not at this location.	Double	8
top_casing_elev	Elevation of the top of casing in feet. Leave null if well is not at this location.	Double	8
datum_value	This field is for by EPA Region 5 future use. Please leave blank.	Double	8
datum_unit	This field is for by EPA Region 5 future use. Please leave blank.	Text	15
step_or_linear	This field is for by EPA Region 5 future use. Please leave blank.	Text	6

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

datum_collect_method_code	This field is for by EPA Region 5 future use. Please leave blank.	Text	2
datum_desc	This field is for by EPA Region 5 future use. Please leave blank.	Text	70
start_date	This field is for by EPA Region 5 future use. Please leave blank.	Date/Time	8

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_SITE

Description: Site Information

Field Name (PK) Primary Key	Description	Type	Length
(PK) site_code	Code indicating site operable unit for which data is collected. Typically code is "01" unless a second or third operable unit exists at facility. Codes of "02" and "03" should be used for second and third operable units, respectively.	Text	3
facility_id	This is equivalent to the three-letter, nine-digit EPA CERCLIS ID number. See Table A-22 in the Appendix for a list of appropriate values.	Text	20
site_name	Name of site. Please use the name as it appears in Table A-1 of the Appendix.	Text	60
site_task_code	Code used to identify the task under which the site or area is investigated. This field is for informational purposes only. Field samples are formally associated with task codes.	Text	10
site_desc1	General description of the site.	Text	255
site_desc2	Additional description of site, if necessary.	Text	255
contact_name	Name of person to contact if EPA Region 5 has any questions about the EDD.	Text	50
address1	Site address, part one.	Text	40
address2	Site address, part two. Default to null if information is not needed	Text	30
city	Site city	Text	30
state	Site state	Text	2
zipcode	Site zip code	Text	10
phone_number	Site contact phone number	Text	30
alt_phone_number	Alternate phone number for site contact. Default to null where the data are not available.	Text	30
fax_number	Fax number of site contact. Default to null where the data are not available.	Text	30
email_address	Site contact e-mail address.	Text	100

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_SMP

Description: Sample IDs

Field Name (PK)	Primary Key	Description	Type	Length
(PK) sys_sample_code		Unique sample identifier. Each sample must have a unique value, including spikes and duplicates. You have considerable flexibility in the methods used to derive and assign unique sample identifiers; however, uniqueness throughout the database is required.	Text	40
sample_name		Additional sample identification information as necessary. Is not required to be unique (i.e., duplicates are OK). Can be the same value as in the sys_sample_code field.	Text	30
sample_matrix_code		Code that identifies the matrix being sampled, such as soil, groundwater, or sediment. For acceptable valid values, see Table A-1 in the Appendix.	Text	3
sample_type_code		Code that distinguishes between different types of samples, such as normal field samples versus laboratory method blank samples. For acceptable valid values see Table A-12 in the Appendix.	Text	3
sample_source		Identifies where the sample originated. Use either "Field" or "Lab". Use "Field" for all samples originating from the field and use "Lab" if sample originated from the laboratory.	Text	5
parent_sample_code		Unique identifier of the original sample from which the current sample was derived, i.e. the "parent" sample. Required for samples with a sample_type_code of "BD", "FD", "FR", "FS", "LR", "MS", "MSD" or "SD."	Text	40
sample_delivery_group		EPA uses Contract Laboratory Program definition of sample delivery group (SDG). Value should correspond to "sampling event/ matrix" with which sample is associated. For example, SDG for ground water samples should be different from SDG for surface water.	Text	10
sample_date		Date sample was collected in MM/DD/YYYY format.	Date/Time	8
sample_time		Time of sample collection in 24-hr (military) HH:MM format. Default to 00:00 if unknown	Date/Time	8
sys_loc_code		Sample collection location. Must be a valid code for the facility. *** Field should be null if sample is not associated with a specific location, such as QC samples (e.g., field blank, trip blank)	Text	20
start_depth		Beginning depth (top) of sample in feet below ground surface. For surface water samples, use beginning depth below water surface elevation. This field should be left null for most ground water samples collected from monitoring wells.	Double	8
end_depth		Ending depth (bottom) of sample in feet below ground surface. For surface water samples, use ending depth below water surface elevation. This field should be left null for most ground water samples collected from monitoring wells.	Double	8
depth_unit		Unit of measurement for the sample beginning and end depths. For valid values, see Table A-18 in the Appendix.	Text	15
chain_of_custody		Chain of custody identifier. A single sample may be	Text	15
sent_to_lab_date		Date sample was sent to lab in MM/DD/YYYY format.	Date/Time	8

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

sample_receipt_date	Date that sample was received at laboratory in MM/DD/YYYY format.	Date/Time	8
sampler	Name or initials of sampler.	Text	30
sampling_company_code	Name or initials of consulting company performing sampling. (This field does not have a controlled vocabulary, i.e., there is no table of valid values for this field.)	Text	10
sampling_reason	Reserved for future use. Report as Null	Text	30
sampling_technique	Sampling technique.	Text	40
task_code	Code for specific sampling event. The format is XX-P#- MM-DD-YYYY. XX is the type of task (PR = Pre Rem., RI = Rem. Inv., FS = Feas. Study, PD = Pre-Design, RD = Rem. Design, RA = Rem. Construction, PC = Post Construction etc.) Day is start date.	Text	20
collection_quarter	Reserved for future use. Report as Null	Text	5
composite_yn	Is sample a composite sample? Enter "Y" for yes or "N" for no.	Text	1
composite_desc	Description of composite sample. If sample is not a composite, leave this field null.	Text	255
sample_class	Reserved for future use. Report as Null	Text	10
sys_well_code	Code used to differentiate between multiple wells installed in same location. If one well exists at a location, use same code as in the sys_loc_code field. For all soil and other samples not associated with a well, insert "None." QA/QC samples get	Text	255
custom_field_2	Reserved for future use. Report as Null	Text	50
custom_field_3	Reserved for future use. Report as Null	Text	50
comment	Any comments regarding the sample.	Text	255

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_TRS

Description: Results - Chemical Test Results

Field Name (PK) Primary Key	Description	Type	Length
(PK) sys_sample_code	Sample identifier of the sample that was tested and analyzed. Must match one of the reported values in the sys_sample_code field of the SMP Table	Text	40
(PK) lab_anl_method_name	Laboratory analytical method name or description. For acceptable valid values, see Table A-16 in the Appendix. Default to "Unknown" if data is unavailable.	Text	35
(PK) analysis_date	Date of sample analysis in MM/DD/YYYY format. May refer to either beginning or end of the analysis.	Date/Time	8
(PK) analysis_time	Beginning time of sample analysis in 24_hr (military) HH:MM format. Note that this field, combined with the "analysis_date" field, is used to distinguish between retests and reruns (if reported).	Date/Time	8
(PK) total_or_dissolved	Must be either "D" for dissolved or filtered [metal] concentrations, and "T" for every other case.	Text	1
column_number	Reserved for future use. Report as Null	Text	2
(PK) test_type	Type of test. Valid values include "Initial," "Reextract1," "Reextract2," "Reextract3," "Reanalysis," "Dilution1," "Dilution2," and "Dilution3."	Text	10
(PK) lab_matrix_code	Code that identifies the matrix, such as soil, groundwater, and sediment, being sampled. Acceptable valid values can be found in Table A-1 of the Appendix..	Text	3
analysis_location	Must be either "FI" for field instrument or probe, "FL" for mobile field laboratory analysis, or "LB" for an analysis done at a fixed-based laboratory.	Text	2
basis	Must be "Wet" for wet-weight basis reporting, "Dry" for dry-weight basis reporting, or "NA" for tests for which this distinction is not applicable. EPA prefers that results are reported on the basis of dry weight where applicable.	Text	3
container_id	Reserved for future use. Report as Null	Text	30
(PK) dilution_factor	Effective test dilution factor.	Single	4
lab_prep_method_name	Laboratory sample preparation method name or description. Must use valid value from Table A-14 in the Appendix.	Text	35
prep_date	Beginning date of sample preparation in MM/DD/YYYY format.	Date/Time	8
prep_time	Beginning time of sample preparation in 24_hr (military) HH:MM format.	Date/Time	8
leachate_method	Laboratory leachate generation method name or description. The method name should be sufficient to reflect the operation methodology used by the laboratory (see analysis method discussion).	Text	15
leachate_date	Beginning date of leachate preparation in MM/DD/YYYY format.	Date/Time	8
leachate_time	Beginning time of leachate preparation in 24hr (military) HH:MM format.	Date/Time	8
lab_name_code	Unique identifier of the laboratory as defined by the EPA. Controlled vocabulary. See Table A-17 in the Appendix for valid codes.	Text	20
qc_level	May be either "screen" for screening data or "quant" for quantitative data. Default value is "quant."	Text	6

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

lab_sample_id	Laboratory LIMS sample identifier. If necessary, a field sample may have more than one LIMS lab_sample_id (maximum one per each test event).	Text	20
percent_moisture	Percent moisture of the sample portion used in this test; this value may vary from test to test for any sample. Numeric format is "NN.MM," i.e., 70.1% could be reported as "70.1" but not as "70.1%."	Text	5
subsample_amount	Amount of sample used for test.	Text	14
subsample_amount_unit	Unit of measurement for subsample amount. Must use valid value from Table A-18 in the Appendix.	Text	15
analyst_name	Reserved for future use. Report as Null	Text	30
instrument_id	Reserved for future use. Report as Null	Text	50
comment	Comments about the test as necessary	Text	255
preservative	Sample preservative used	Text	50
final_volume	The final volume of the sample after sample preparation. Include all dilution factors.	Text	15
final_volume_unit	The unit of measure that corresponds to the final_amount.	Text	15
(PIC) cas_in	Analyte code. See Table A-15 in the Appendix for acceptable valid values.	Text	15
chemical_name	Chemical name. Use the appropriate name from Table A-15 in the Appendix.	Text	75
result_value	Analytical result reported at an appropriate number of significant digits.	Text	20
result_error_delta	Error range applicable to the result value; typically used only for radiochemistry results.	Text	20
result_type_code	Must be either "TRG" for a target or regular result, "TIC" for a tentatively identified compound.	Text	3
reportable_result	Must be either "Yes" for results that are considered to be reportable, or "No" for other results. This field has many purposes. For example, it can be used to distinguish between multiple results where a sample is retested after dilution.	Text	3
detect_flag	Maybe either "Y" for detected analytes or "N" for nondetects.	Text	1
lab_qualifiers	Qualifier flags assigned by the laboratory. For acceptable valid values see Table A-10 in the Appendix.	Text	2
validator_qualifiers	Qualifier flags assigned by the person who validates the laboratory data. For acceptable valid values see Table A-10 in the Appendix.	Text	2
organic_yn	Must be either "Y" for organic constituents or "N" for inorganic constituents.	Text	1
method_detection_limit	Report as null. The minimum concentration of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, as determined for a specific procedure.	Text	20
reporting_detection_limit	Must be reported if sample result is "non-detect." The minimum conc. of an analyte that can be measured and reported with 99% confidence that the analyte conc. >0, as determined for a specific procedure, which is equal to or greater than the MDL.	Text	20
quantitation_limit	Concentration level above which results can be quantified with confidence. The value must reflect conditions such as dilution factors and moisture content, and must be sample-specific.	Text	20

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

result_unit	Units of measurement for the result. Must use valid values from Table A-18 in the Appendix.	Text	25
detection_limit_unit	Units of measurement for the detection limit(s). Must use valid value from Table A-18 in the Appendix.	Text	15
tic_retention_time	EPA says "Reserved for future use. Report as Null" in guidance, however I suggestion deviating from this - RAS 10/19/06	Text	255
result_comment	Result specific comments.	Text	255

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_TRSQC

Description: Results - Chemical Test Results with QC Data

Field Name (PK)	Primary Key	Description	Type	Length
sys_sample_code		Sample identifier of the sample that was tested and analyzed. Must match one of the reported values in the sys_sample_code field of the SMP Table	Text	40
lab_anl_method_name		Laboratory analytical method name or description. For acceptable valid values, see Table A-16 in the Appendix. Default to "Unknown" if data is unavailable.	Text	35
analysis_date		Date of sample analysis in MM/DD/YYYY format. May refer to either beginning or end of the analysis.	Date/Time	8
analysis_time		Beginning time of sample analysis in 24_hr (military) HH:MM format. Note that this field, combined with the "analysis_date" field, is used to distinguish between retests and reruns (if reported).	Date/Time	8
total_or_dissolved		Must be either "D" for dissolved or filtered [metal] concentrations, and "T" for every other case.	Text	1
column_number		Reserved for future use. Report as Null	Text	2
test_type		Type of test. Valid values include "initial," "reextract1," "reextract2," "reextract3," "reanalysis," "dilution1," "dilution2," and	Text	10
lab_matrix_code		Code that identifies the matrix, such as soil, groundwater, and sediment, being sampled. Acceptable valid values can be found in Table A-1 of the Appendix.	Text	3
analysis_location		Must be either "FI" for field instrument or probe, "FL" for mobile field laboratory analysis, or "LB" for an analysis done at a fixed-based laboratory.	Text	2
basis		Must be "Wet" for wet-weight basis reporting, "Dry" for dry-weight basis reporting, or "NA" for tests for which this distinction is not applicable. EPA prefers that results are reported on the basis of dry weight where applicable.	Text	3
container_id		Reserved for future use. Report as Null	Text	30
dilution_factor		Effective test dilution factor.	Single	4
lab_prep_method_name		Laboratory sample preparation method name or description. Must use valid value from Table A-14 in the Appendix.	Text	35
prep_date		Beginning date of sample preparation in MM/DD/YYYY format.	Date/Time	8
prep_time		Beginning time of sample preparation in 24_hr (military) HH:MM format.	Date/Time	8
leachate_method		Laboratory leachate generation method name or description. The method name should be sufficient to reflect the operation methodology used by the laboratory (see analysis method discussion).	Text	15
leachate_date		Beginning date of leachate preparation in MM/DD/YYYY format.	Date/Time	8
leachate_time		Beginning time of leachate preparation in 24hr (military) HH:MM format.	Date/Time	8
lab_name_code		Unique identifier of the laboratory as defined by the EPA. Controlled vocabulary. See Table A-17 in the Appendix for valid codes.	Text	20
qc_level		May be either "screen" for screening data or "quant" for quantitative data. Default value is "quant."	Text	6

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

lab_sample_id	Laboratory LIMS sample identifier. If necessary, a field sample may have more than one LIMS lab_sample_id (maximum one per each test event).	Text	20
percent_moisture	Percent moisture of the sample portion used in this test; this value may vary from test to test for any sample. Numeric format is "NN.MM," i.e., 70.1% could be reported as "70.1" but not as "70.1%."	Text	5
subsample_amount	Amount of sample used for test.	Text	14
subsample_amount_unit	Unit of measurement for subsample amount. Must use valid value from Table A-18 in the Appendix.	Text	15
analyst_name	Reserved for future use. Report as Null	Text	30
instrument_id	Reserved for future use. Report as Null	Text	50
comment	Comments about the test as necessary	Text	255
preservative	Sample preservative used	Text	50
final_volume	The final volume of the sample after sample preparation. Include all dilution factors.	Text	15
final_volume_unit	The unit of measure that corresponds to the final_amount.	Text	15
cas_n	Analyte code. See Table A-15 in the Appendix for acceptable valid values.	Text	15
chemical_name	Chemical name. Use the appropriate name from Table A-15 in the Appendix.	Text	75
result_value	Analytical result reported at an appropriate number of significant digits.	Text	20
result_error_delta	Error range applicable to the result value; typically used only for radiochemistry results.	Text	20
result_type_code	Must be either "TRG" for a target or regular result, "TIC" for a tentatively identified compound.	Text	3
reportable_result	Must be either "Yes" for results that are considered to be reportable, or "No" for other results. This field has many purposes. For example, it can be used to distinguish between multiple results where a sample is retested after dilution.	Text	3
detect_flag	Maybe either "Y" for detected analytes or "N" for nondetects.	Text	1
lab_qualifiers	Qualifier flags assigned by the laboratory. For acceptable valid values see Table A-10 in the Appendix.	Text	2
validator_qualifiers	Qualifier flags assigned by the person who validates the laboratory data. For acceptable valid values see Table A-10 in the Appendix.	Text	2
organic_yn	Must be either "Y" for organic constituents or "N" for inorganic constituents.	Text	1
method_detection_limit	Report as null. The minimum concentration of an analyte that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, as determined for a specific procedure.	Text	20
reporting_detection_limit	Must be reported if sample result is "non-detect." The minimum conc. of an analyte that can be measured and reported with 99% confidence that the analyte conc. >0, as determined for a specific procedure, which is equal to or greater than the MDL.	Text	20
quantitation_limit	Concentration level above which results can be quantified with confidence. The value must reflect conditions such as dilution factors and moisture content, and must be sample-specific.	Text	20

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

result_unit	Units of measurement for the result. Must use valid values from Table A-18 in the Appendix.	Text	15
detection_limit_unit	Units of measurement for the detection limit(s). Must use valid value from Table A-18 in the Appendix.	Text	15
tie_retention_time	EPA says "Reserved for future use. Report as Null" in guidance, however I suggestion deviating from this - RAS 10/19/06	Text	255
result_comment	Result specific comments.	Text	255
qc_original_conc	The concentration of the analyte in the original (unspiked) sample. Might be required for spikes and spike duplicates (depending on user needs). Not necessary for surrogate compounds or LCS samples (where the original concentration is assumed to be zero).	Text	14
qc_spike_added	The concentration of the analyte added to the original sample. Might be required for spikes, spike duplicates, surrogate compounds, LCS and any spiked sample (depending on user needs).	Text	14
qc_spike_measured	The measured concentration of the analyte. Use zero for spiked compounds that were not detected in the sample. Might be required for spikes, spike duplicates, surrogate compounds, LCS and any spiked sample (depending on user needs).	Text	14
qc_spike_recovery	The percent recovery calculated as specified by the laboratory QC program. Always required for spikes, spike duplicates, surrogate compounds, LCS and any spiked sample. Report as percentage multiplied by 100 (e.g., report "120%" as "120").	Text	14
qc_dup_original_conc	Conc. of the analyte in the original (unspiked) sample. Might be required for spike or LCS duplicates only (depending on user needs). Not necessary for surrogate compounds or LCS samples (where the original conc. is assumed to be zero).	Text	14
qc_dup_spike_added		Text	14
qc_dup_spike_measured		Text	14
qc_dup_spike_recovery		Text	14
qc_rpd		Text	8
qc_spike_lcl		Text	8
qc_spike_ucl		Text	8
qc_rpd_cl		Text	8
qc_spike_status		Text	1
qc_dup_spike_status		Text	1

Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Table: DA_WEL

Description: Wells

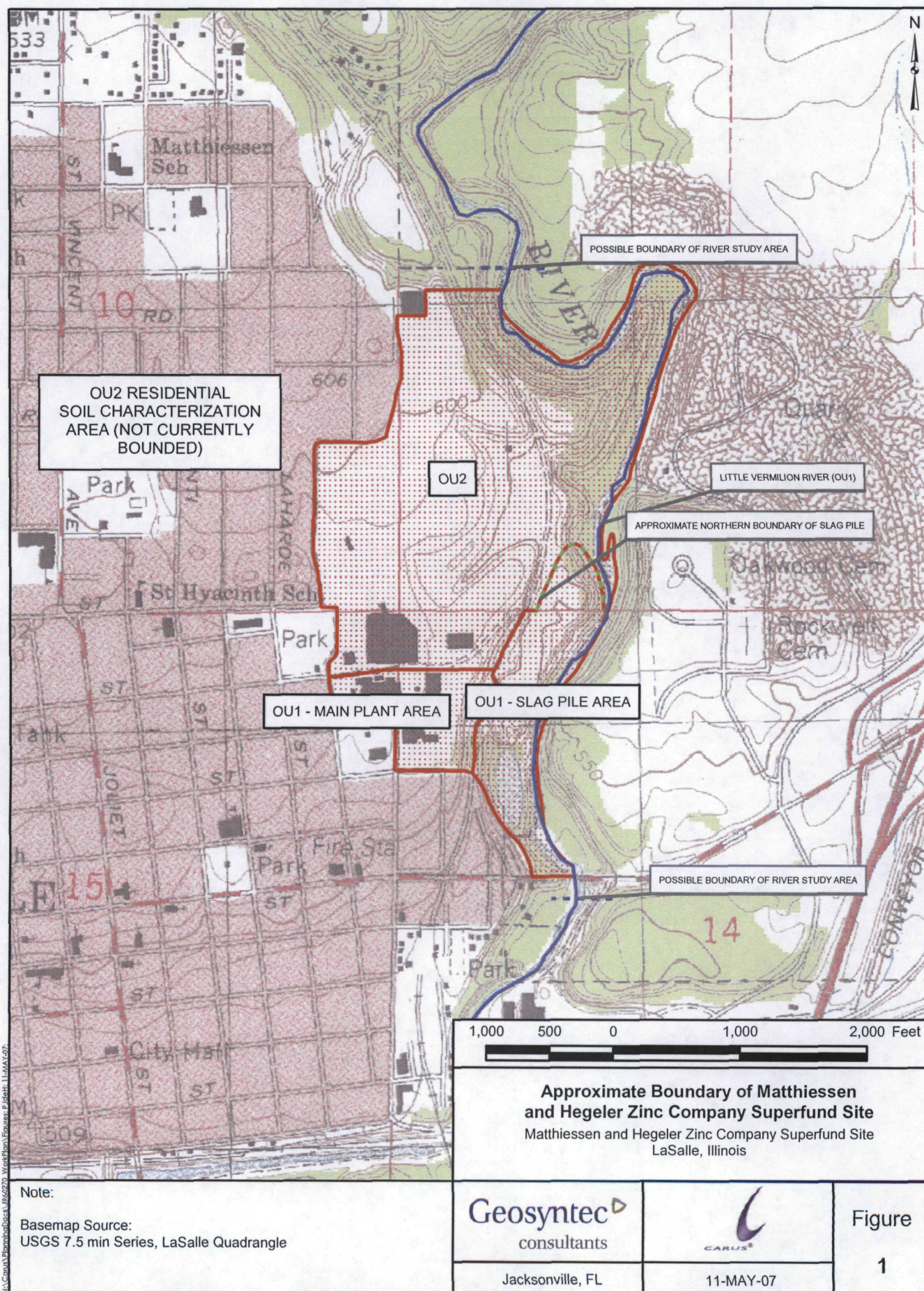
Field Name (PK) Primary Key	Description	Type	Length
(PK) sys_loc_code	Location ID, such as MW-01, A24, SW12, or SB-2S, for all samples collected, including groundwater samples, hydropunch samples, surface water/sediment samples, and soil samples.	Text	20
sys_well_code	Code used to differentiate between multiple wells installed at the same location. If one well exists, use sys_loc_code field. For surface water samples use "Surface". For all soil and other samples not associated with a well, insert "None."	Text	20
well_description	Used for additional well description if necessary.	Text	30
well_owner	Name of entity that owns the well.	Text	30
well_purpose	Purpose of well	Text	20
well_status	Current status of well	Text	20
top_casing_elev	Elevation of the top of well casing. Elevation must be in feet.	Single	4
datum_value	Elevation of datum used to reference measurement of water level depths. (EPA normally uses top of well casing for datum).	Single	4
datum_unit	Unit of measure for the well datum. See Table A-18 for appropriate values	Text	15
datum_desc	Description of the datum, such as "top of well casing."	Text	70
step_or_linear	Use only for re-surveys of well elevations. If a section of the well casing was removed or added use "step" as the value. If nothing was added or removed from the last survey, use "linear" as the value	Text	6
start_date	Date that datum was first used to take measurements in MM/DD/YYYY format.	Date/Time	8
datum_collect_method_code	Method used to determine the datum elevation. Use codes from Table A-6 in Appendix.	Text	2
depth_of_well	Depth below ground surface of the well bottom.	Single	4
depth_unit	Unit of measurement for depth. Use values from Table A-18	Text	15
depth_measure_method	Method of measuring depth of well.	Text	20
stickup_height	Height of casing above ground surface.	Text	8
stickup_unit	Unit of measure for the stickup height. Use values from Table A-18.	Text	15
sump_length	Length of sump.	Text	20
sump_unit	Unit of measure for the sump length. Use values from Table A-18.	Text	15
installation_date	Date of well installation in MM/DD/YYYY format	Date/Time	8
construct_start_date	Date well construction began in MM/DD/YYYY format	Date/Time	8
construct_complete_date	Date well construction was complete in MM/DD/YYYY format	Date/Time	8
construct_contractor	Name of contractor that installed well	Text	20
pump_type	Type of pump used at well such as centrifugal, propeller, jet, helical, rotary, etc.	Text	20
pump_capacity	Capacity of pump	Text	6

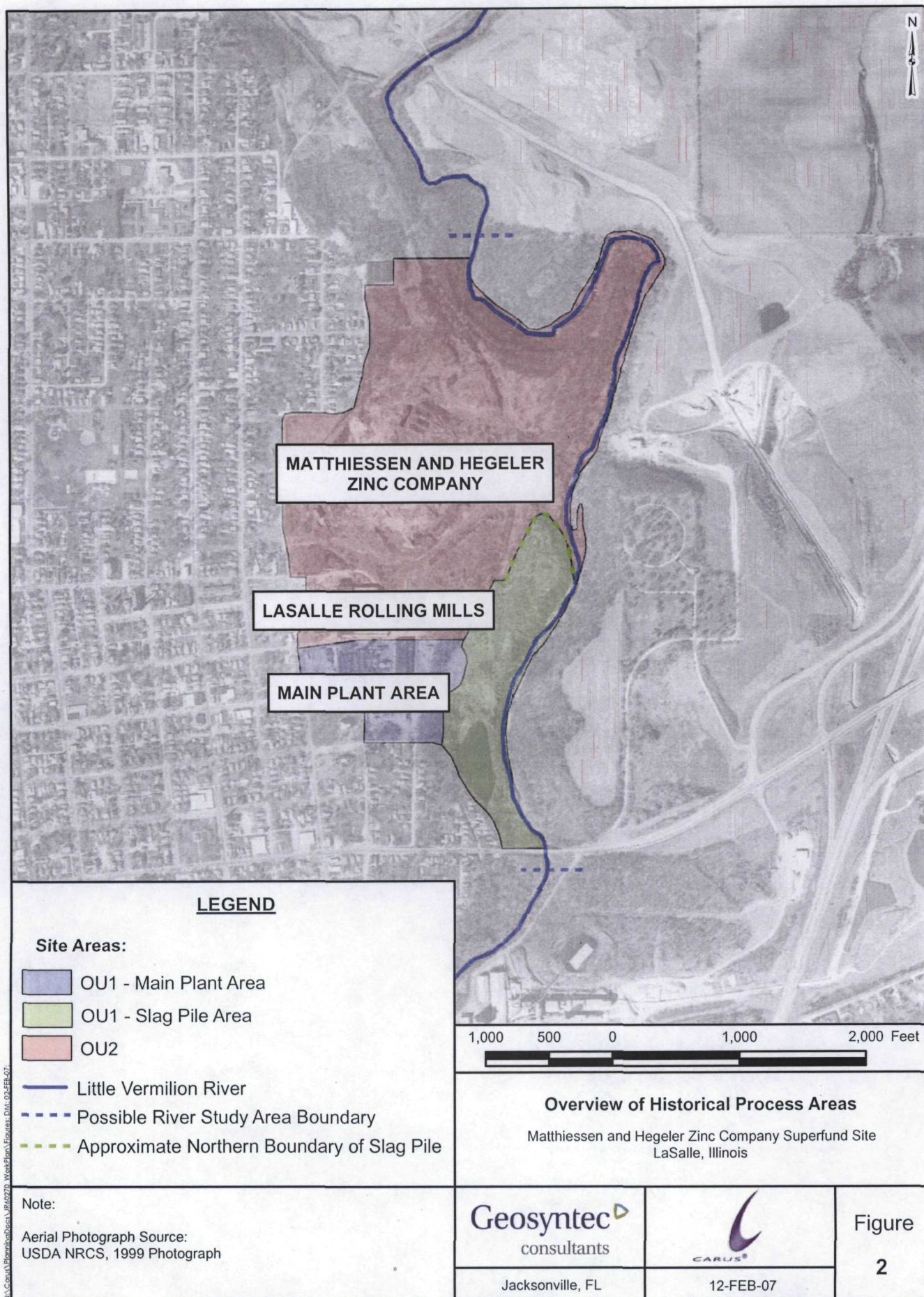
Table 7. Database Documentation
Remedial Investigation/Feasibility Study
Matthiessen & Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

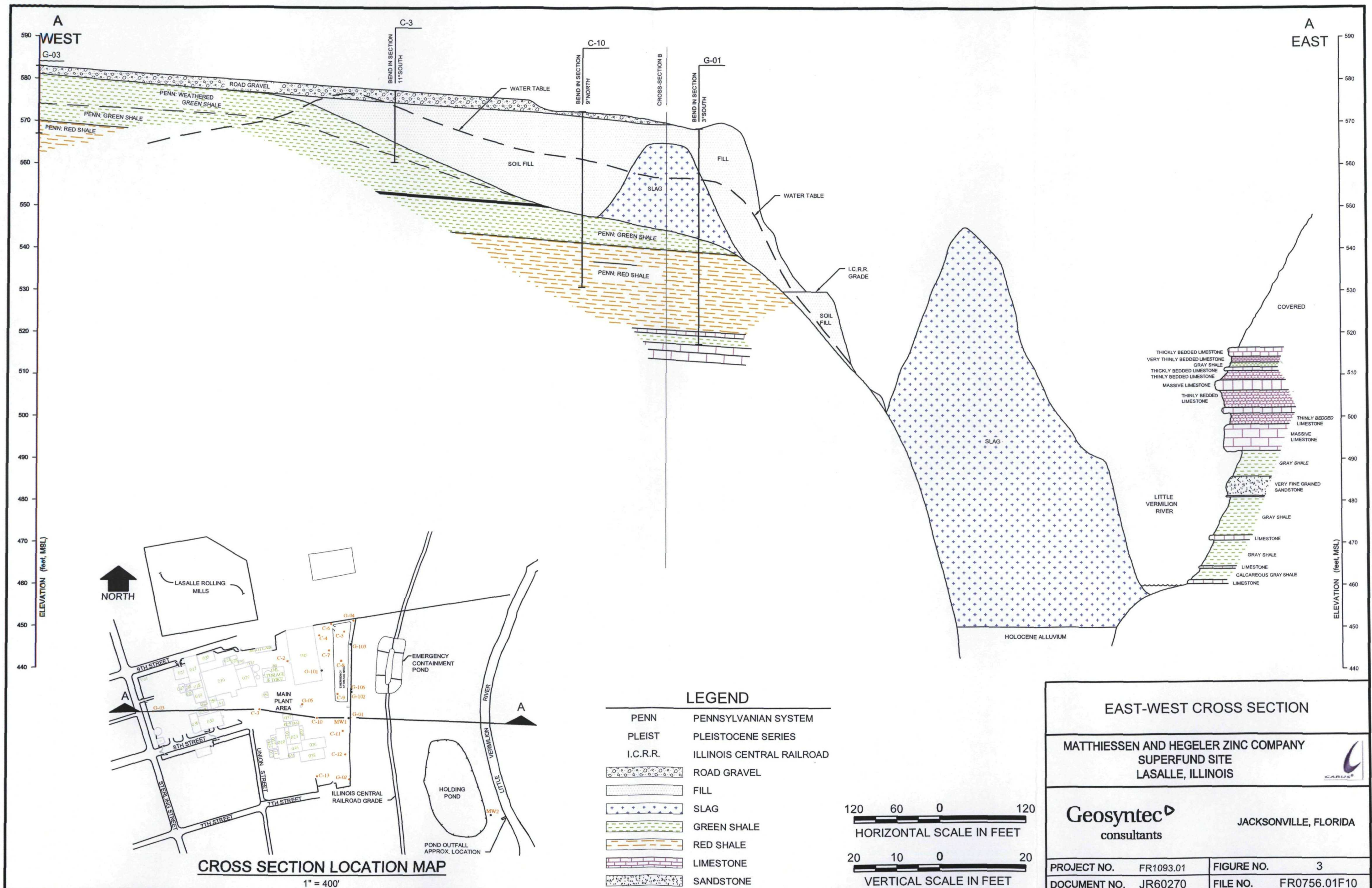
pump_unit	Unit of measure for the pump capacity and yield. Use values from Table A-18	Text	15
pump_yield	Yield of the pump	Text	6
pump_yield_method	Method used for the pump yield	Text	20
weep_hole	Is there a weep hole? "Y" or "N"	Text	1
head_configuration	Description of the wellhead	Text	50
access_port_yn	Is there an access port? "Y" or "N"	Text	1
casing_joint_type	Type of casing joint, such as "threaded," "flush," or "solvent welded."	Text	50
perforator_used	Description of well perforation such as "slotted", "drilled", or "wound".	Text	50
intake_depth	Depth in feet below ground surface of the well intake	Single	4
disinfected_yn	Was well disinfected? "Y" or "N"	Text	1
historical_reference_elev	Leave null	Single	4
geologic_unit_code	Geologic unit in which the well intake is installed	Text	20
remark	Available for general remarks.	Text	255

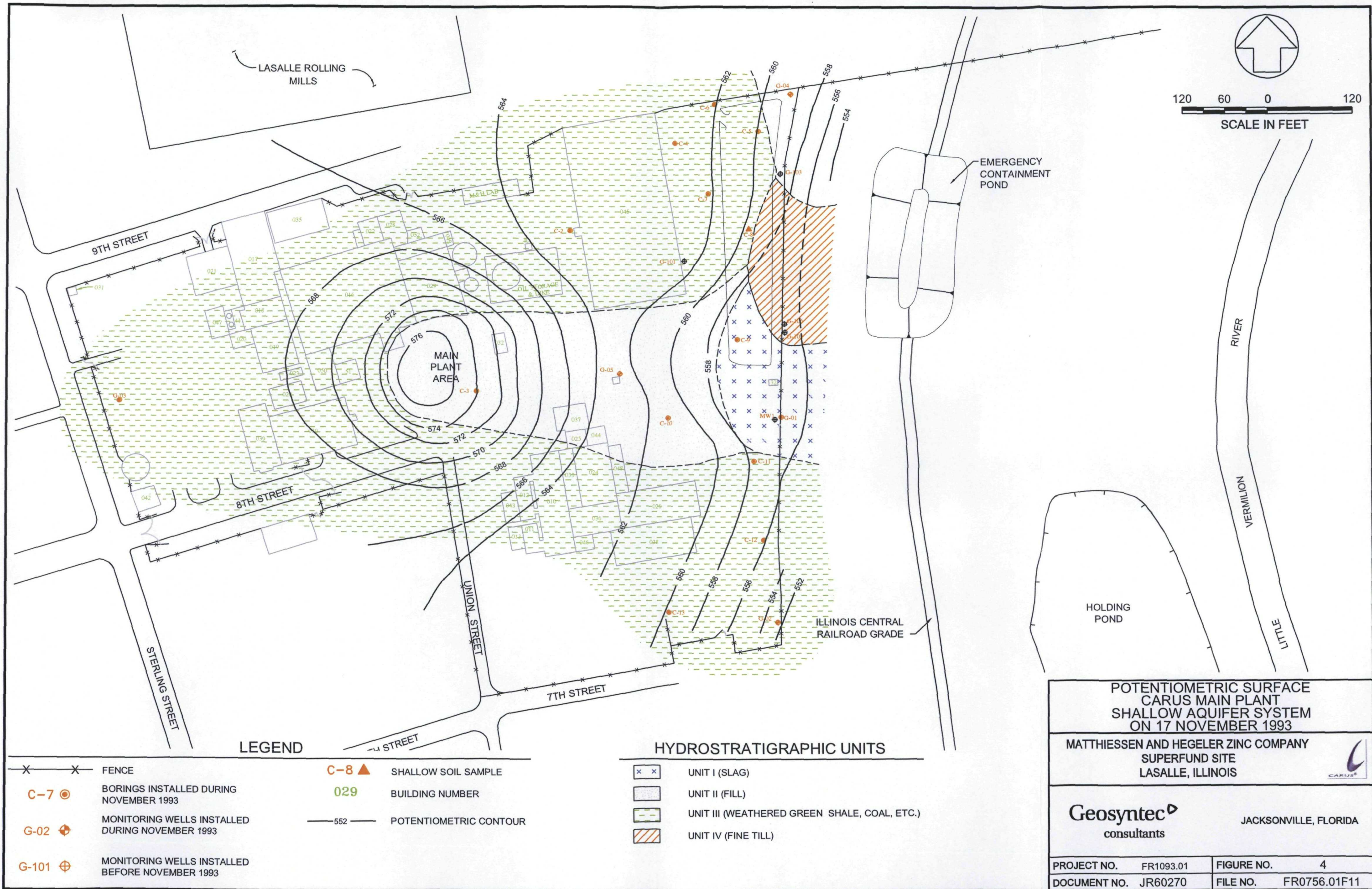
FIGURES

1

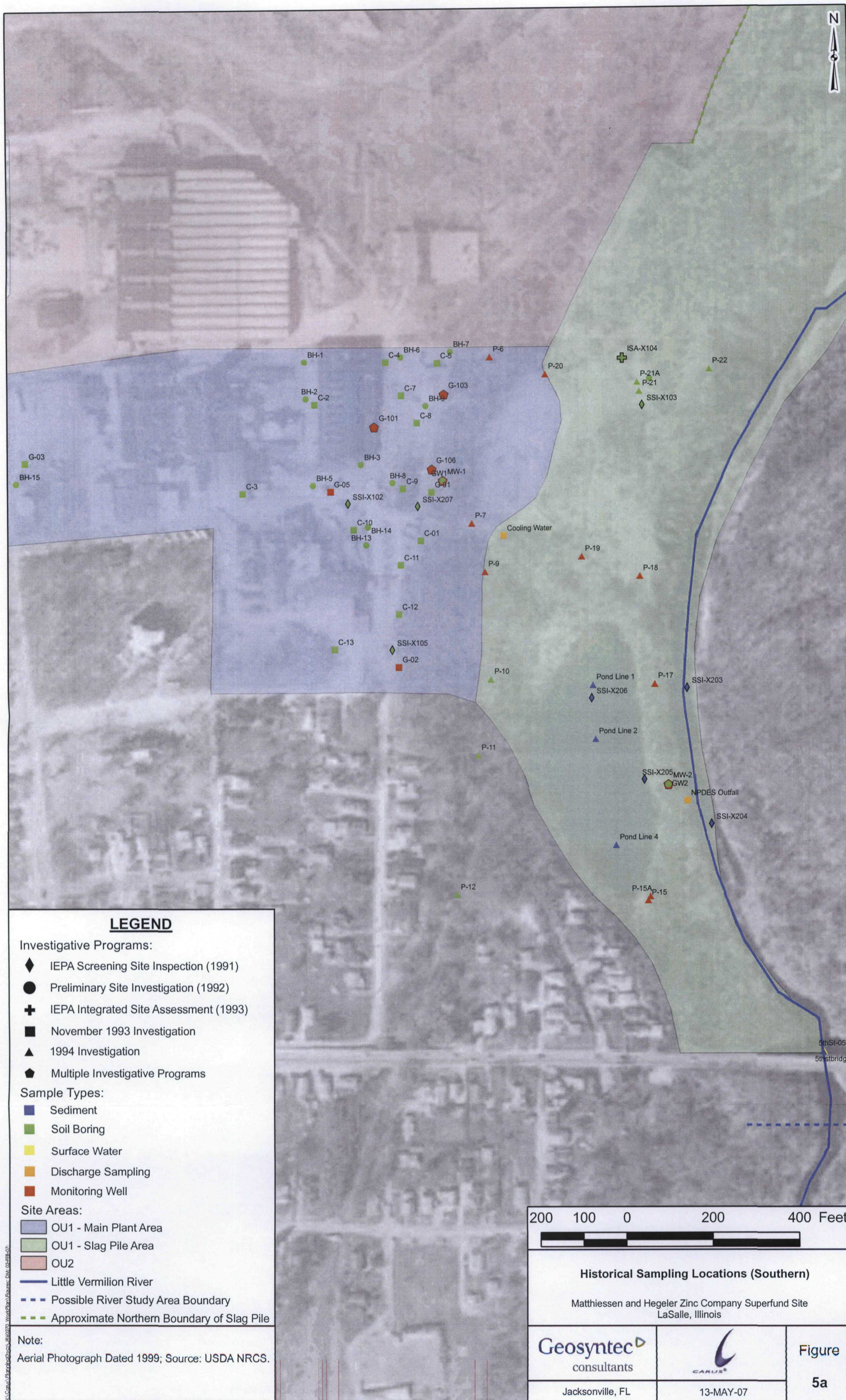


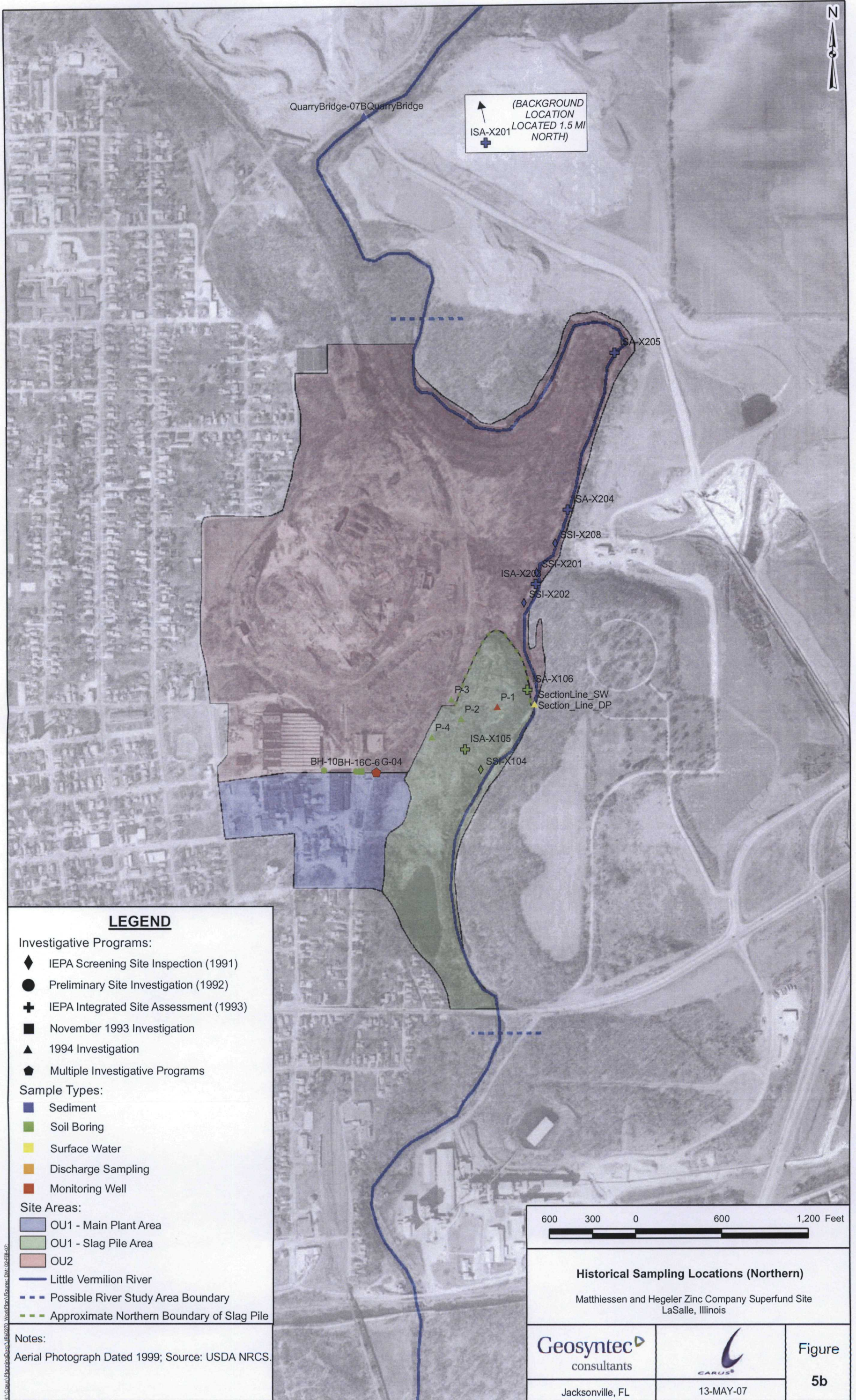




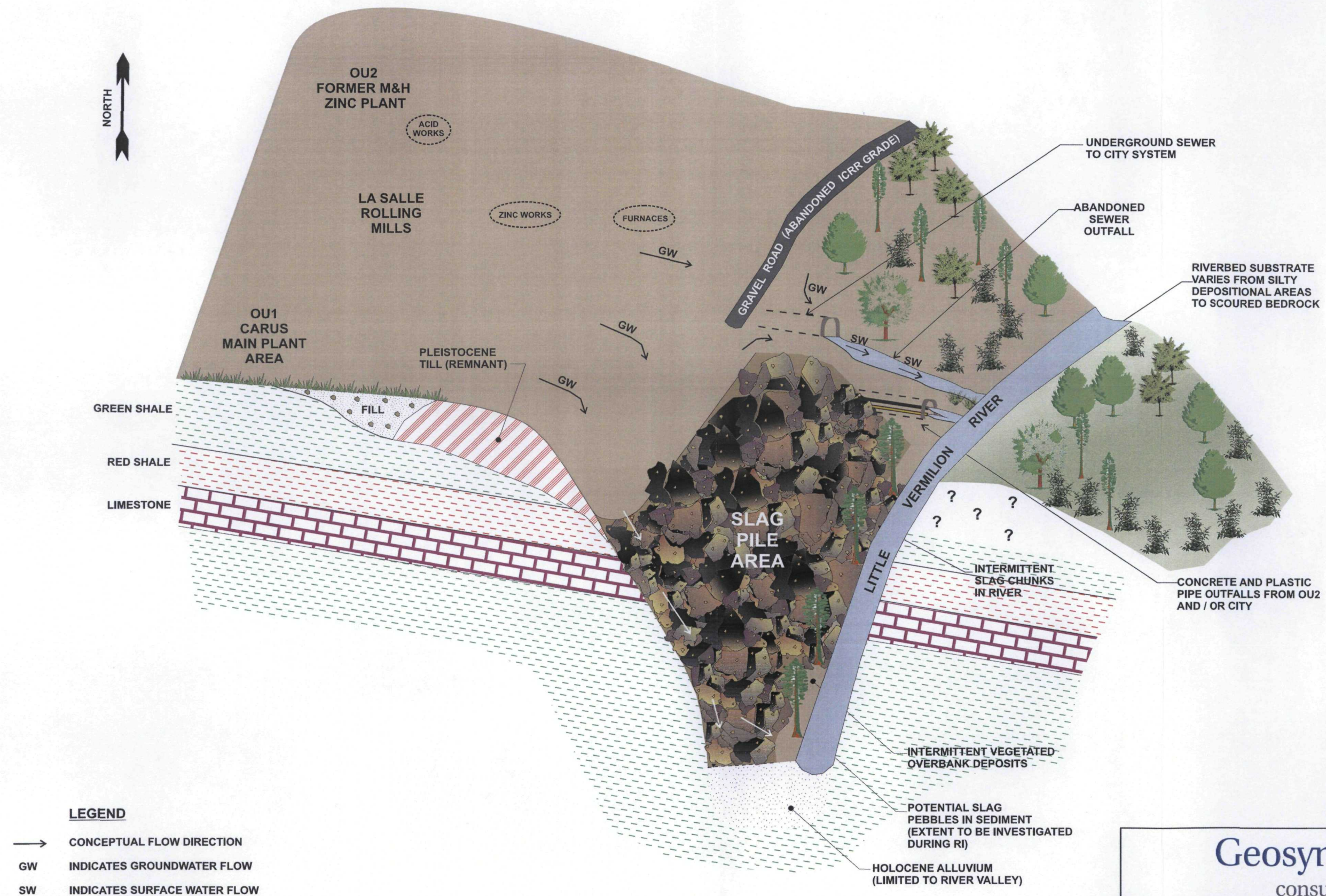


POTENTIOMETRIC SURFACE CARUS MAIN PLANT SHALLOW AQUIFER SYSTEM ON 17 NOVEMBER 1993	
MATTHIESSEN AND HEGELER ZINC COMPANY SUPERFUND SITE LASALLE, ILLINOIS	
<div> <div> Geosyntec consultants </div> <div> JACKSONVILLE, FLORIDA </div> </div>	
PROJECT NO. FR1093.01	FIGURE NO. 4
DOCUMENT NO. JR60270	FILE NO. FR0756.01F11





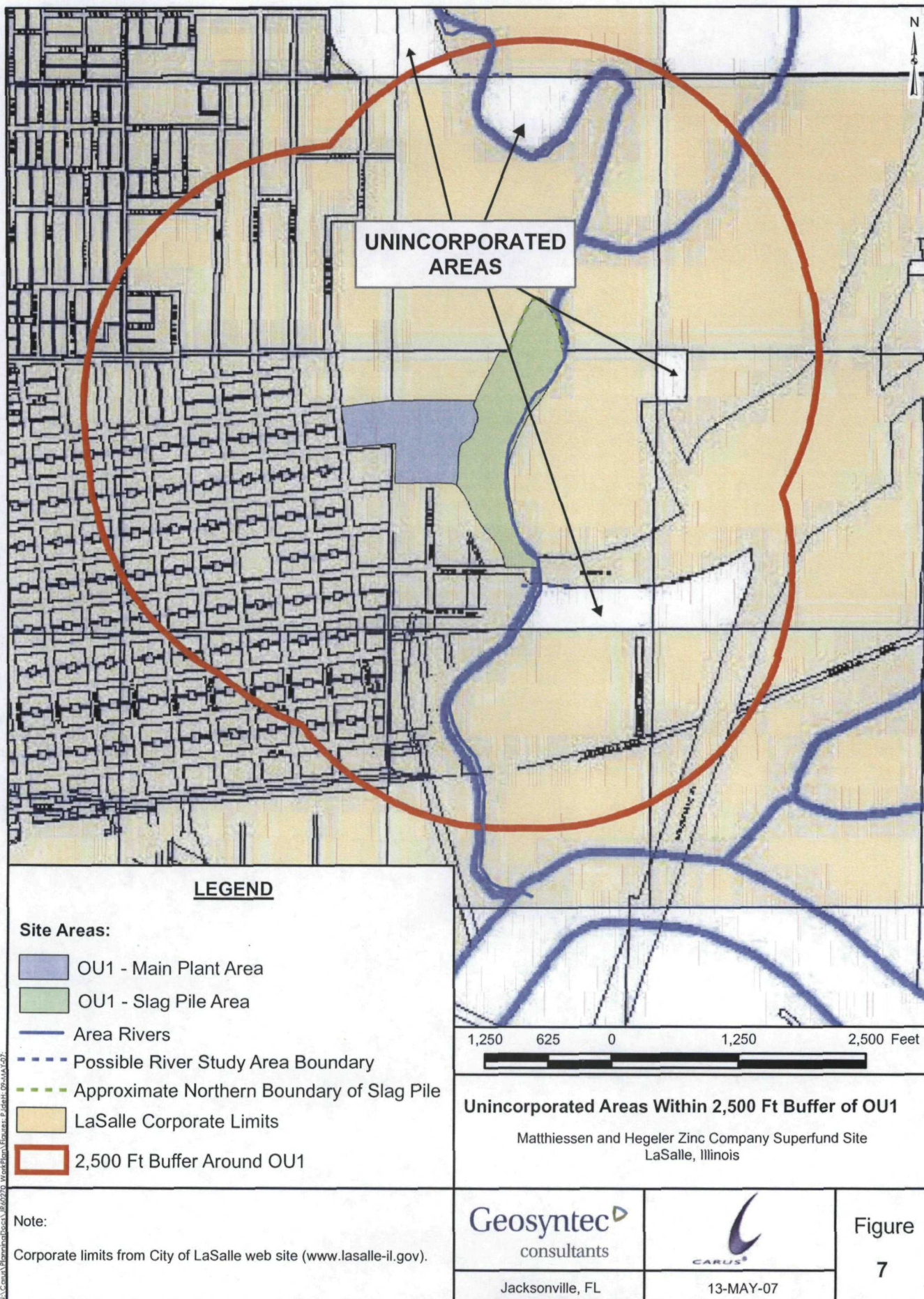
PHYSICAL CONCEPTUAL SITE MODEL OF UPLAND PROCESS AREAS, SLAG PILE, AND RIVER

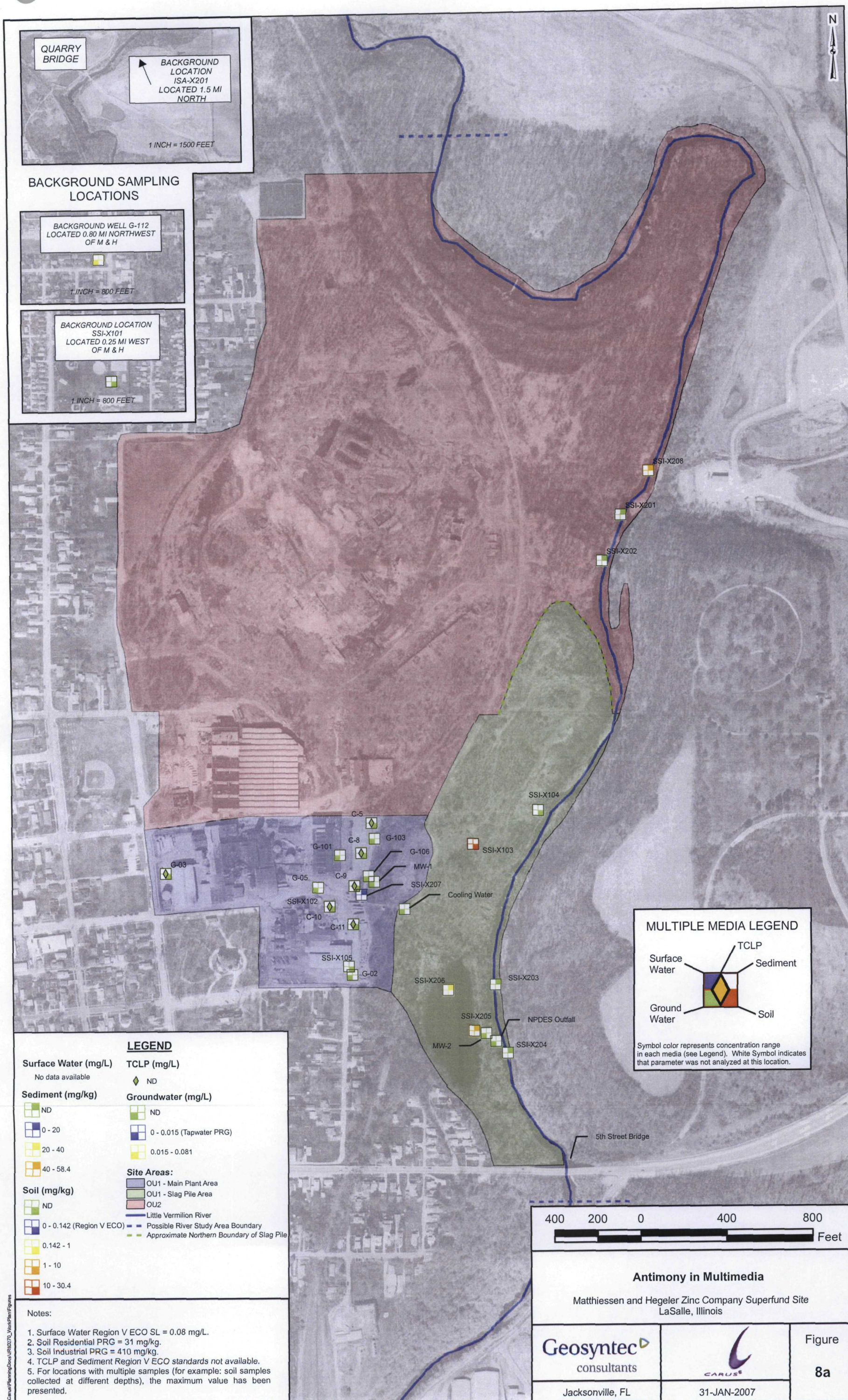


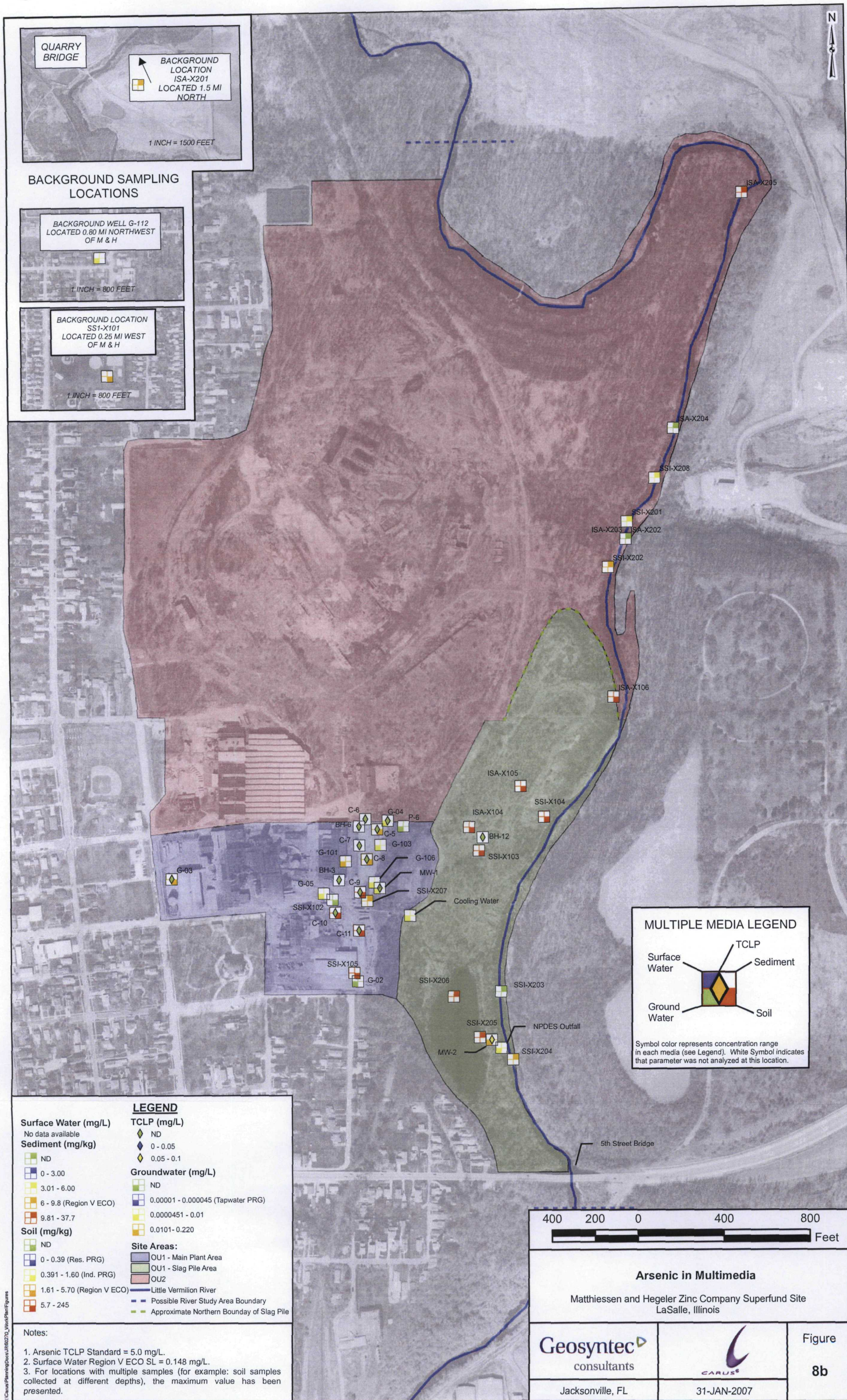
NOTE: NOT TO SCALE

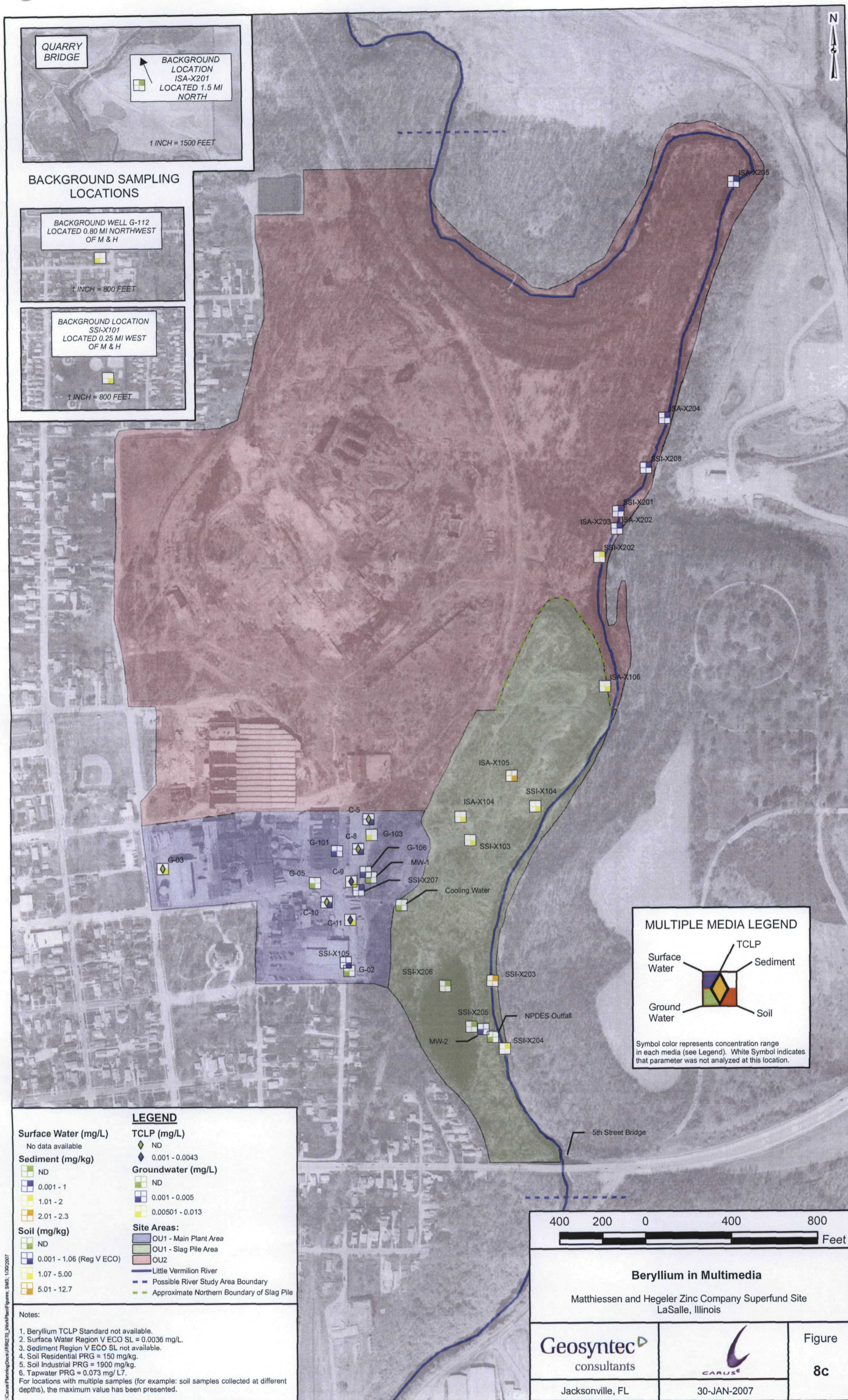
Geosyntec
consultants

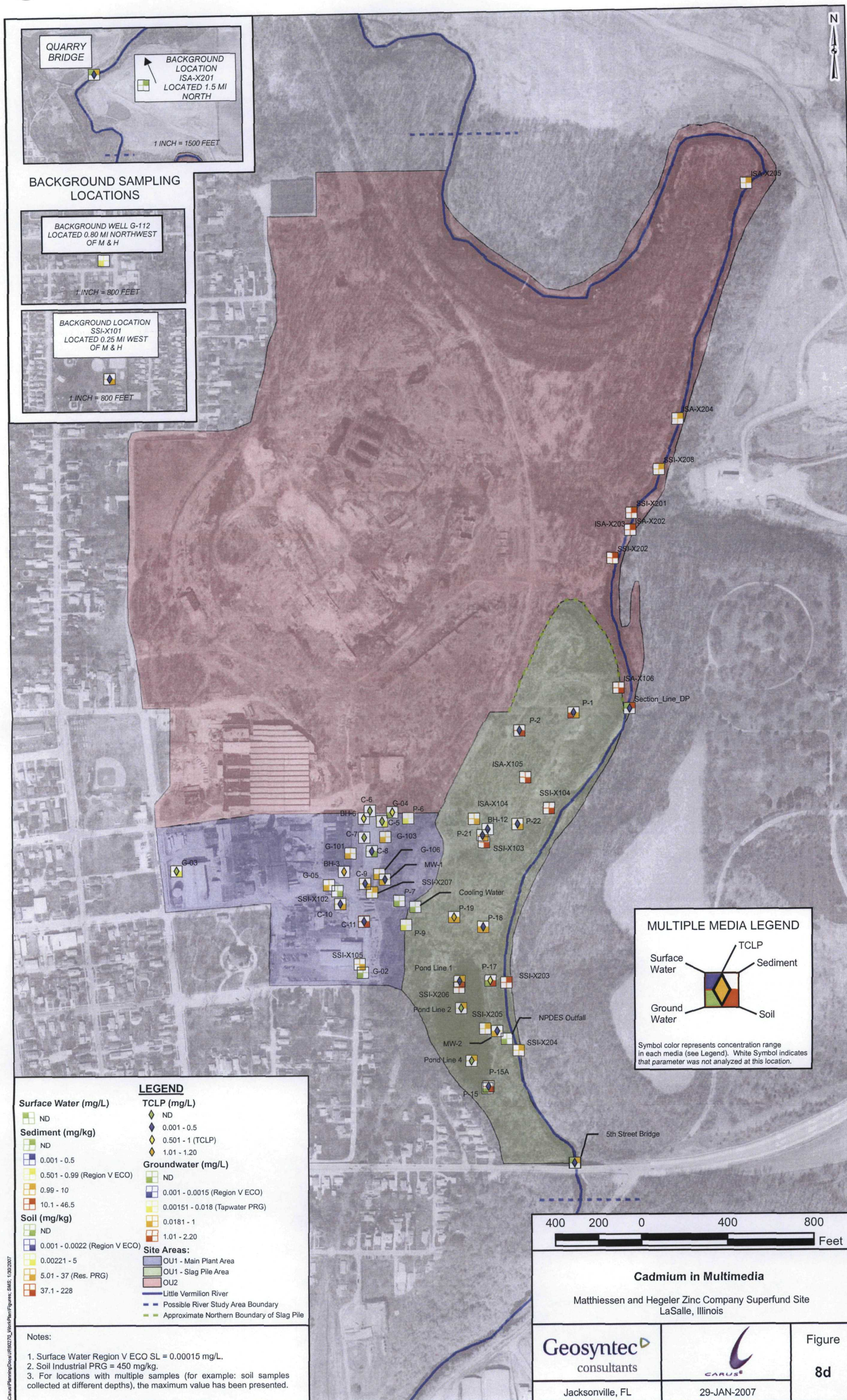
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DOCUMENT NO.	JR60270	FILE NO.	1093F001.CDR

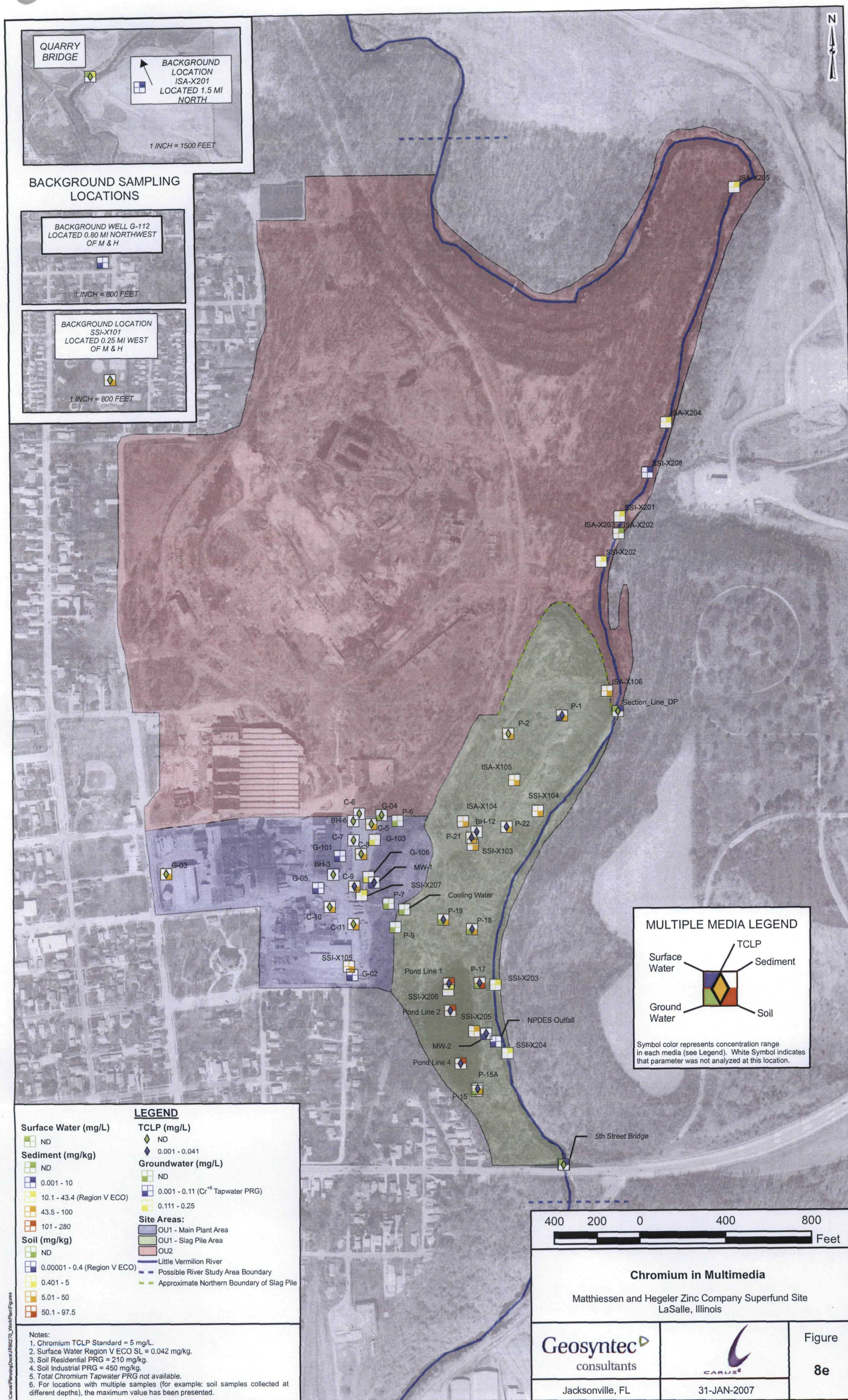


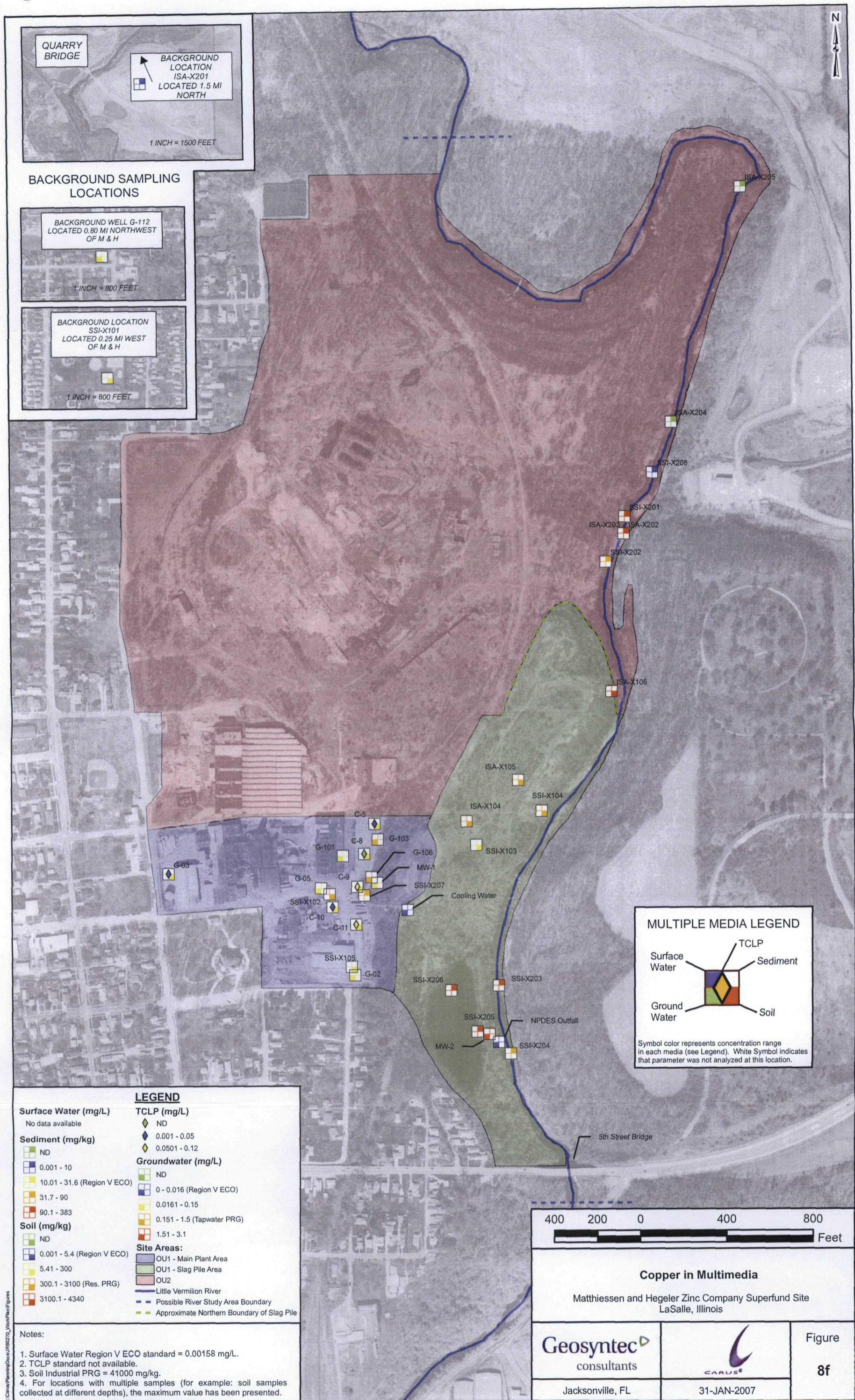


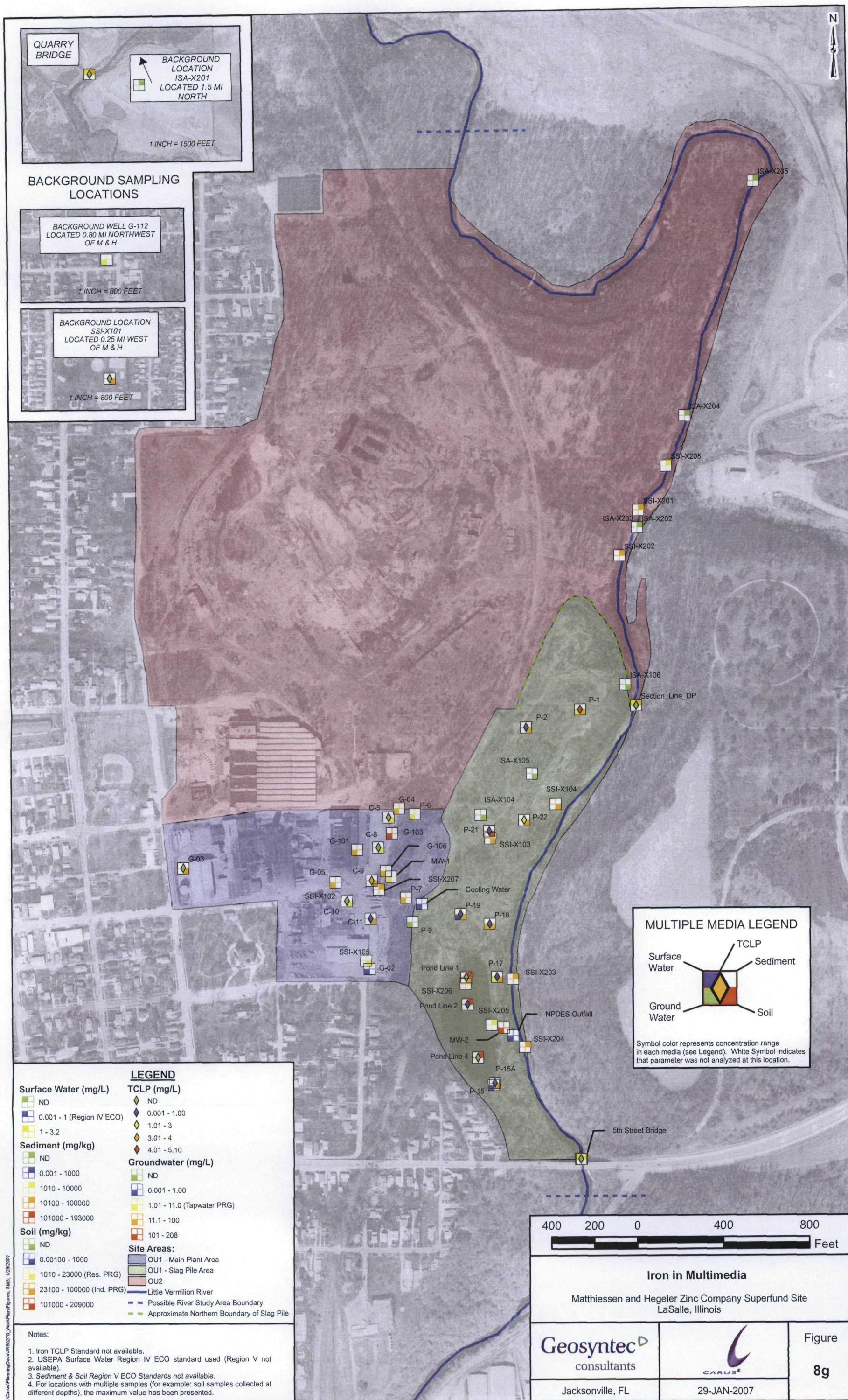


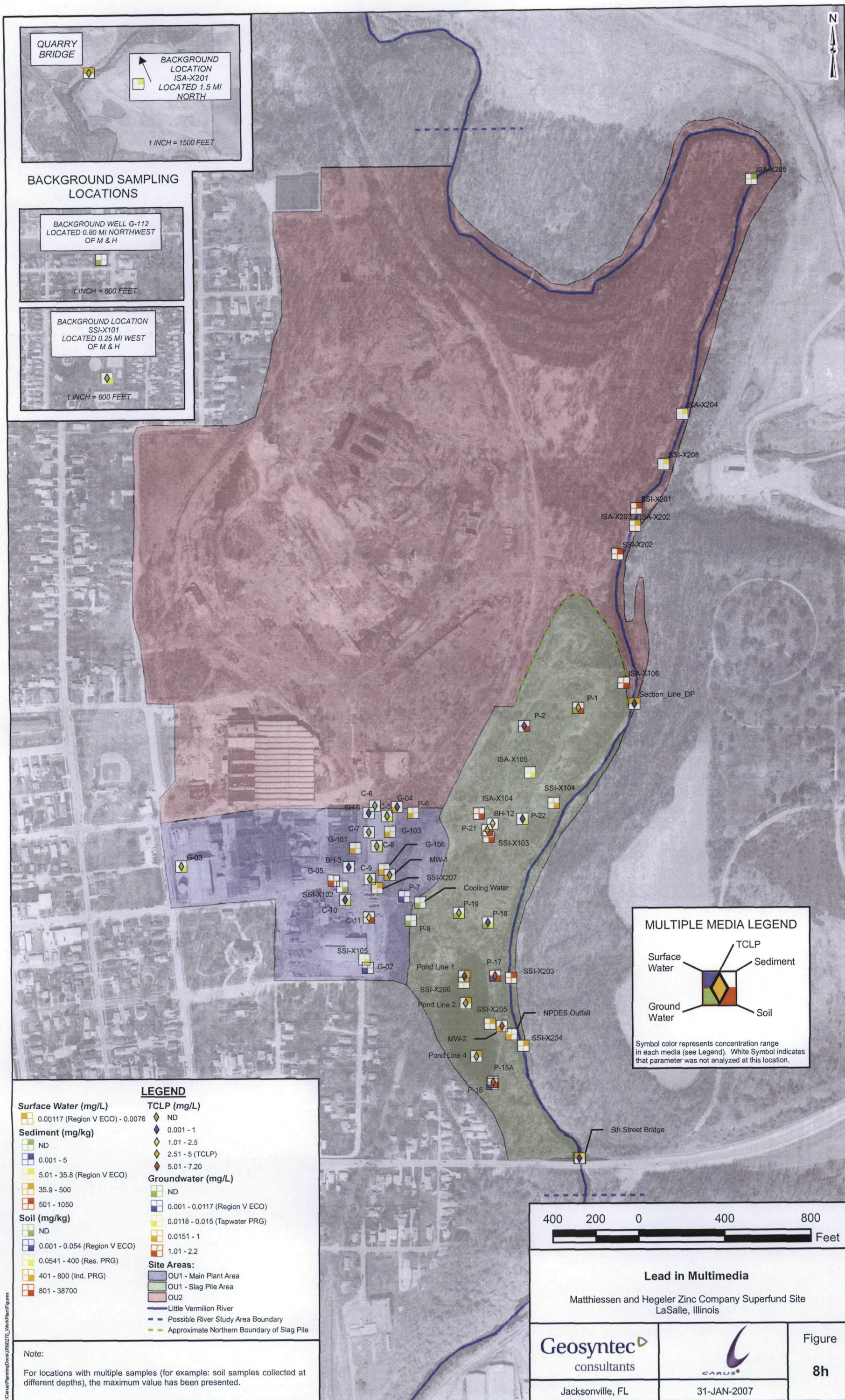


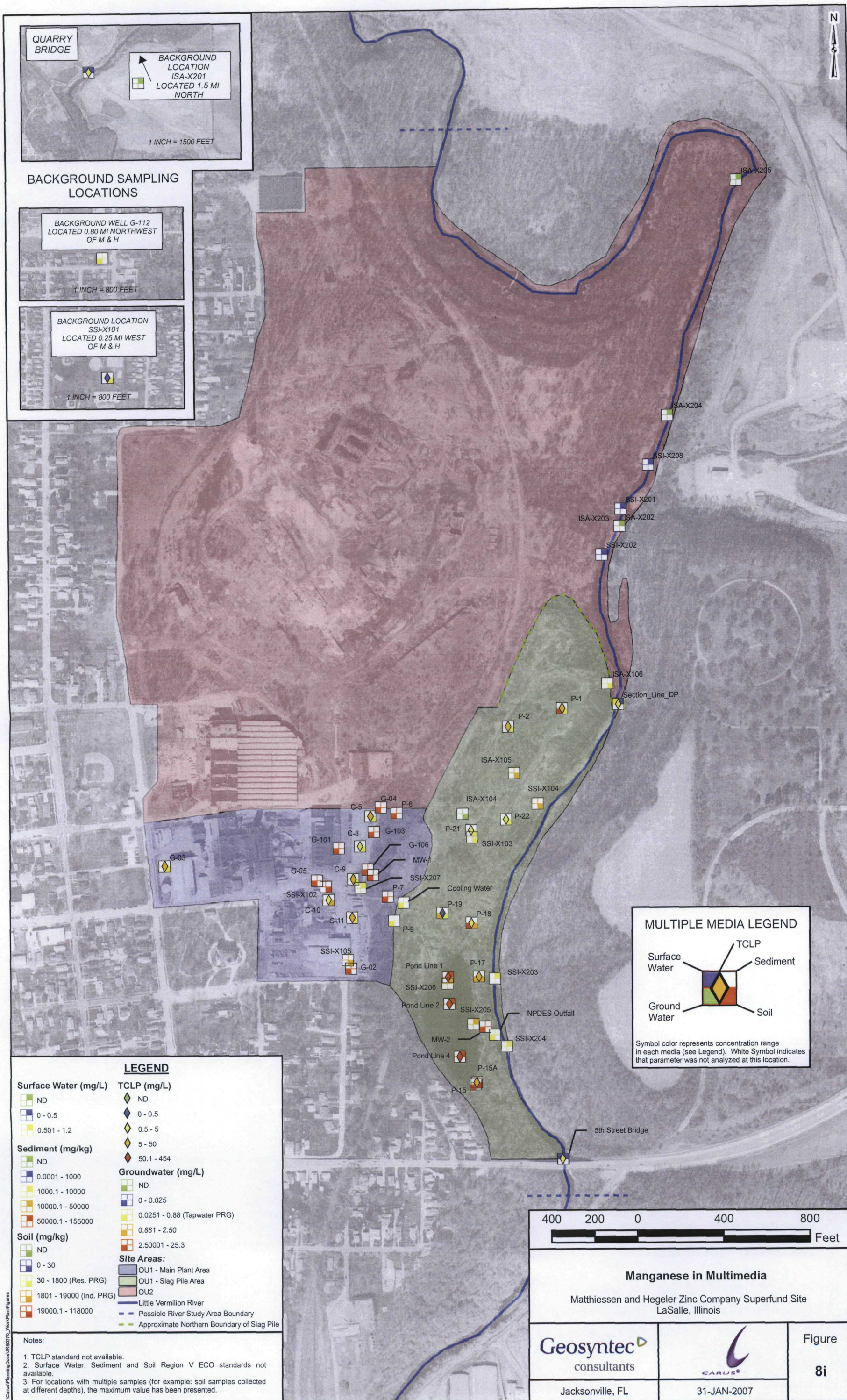


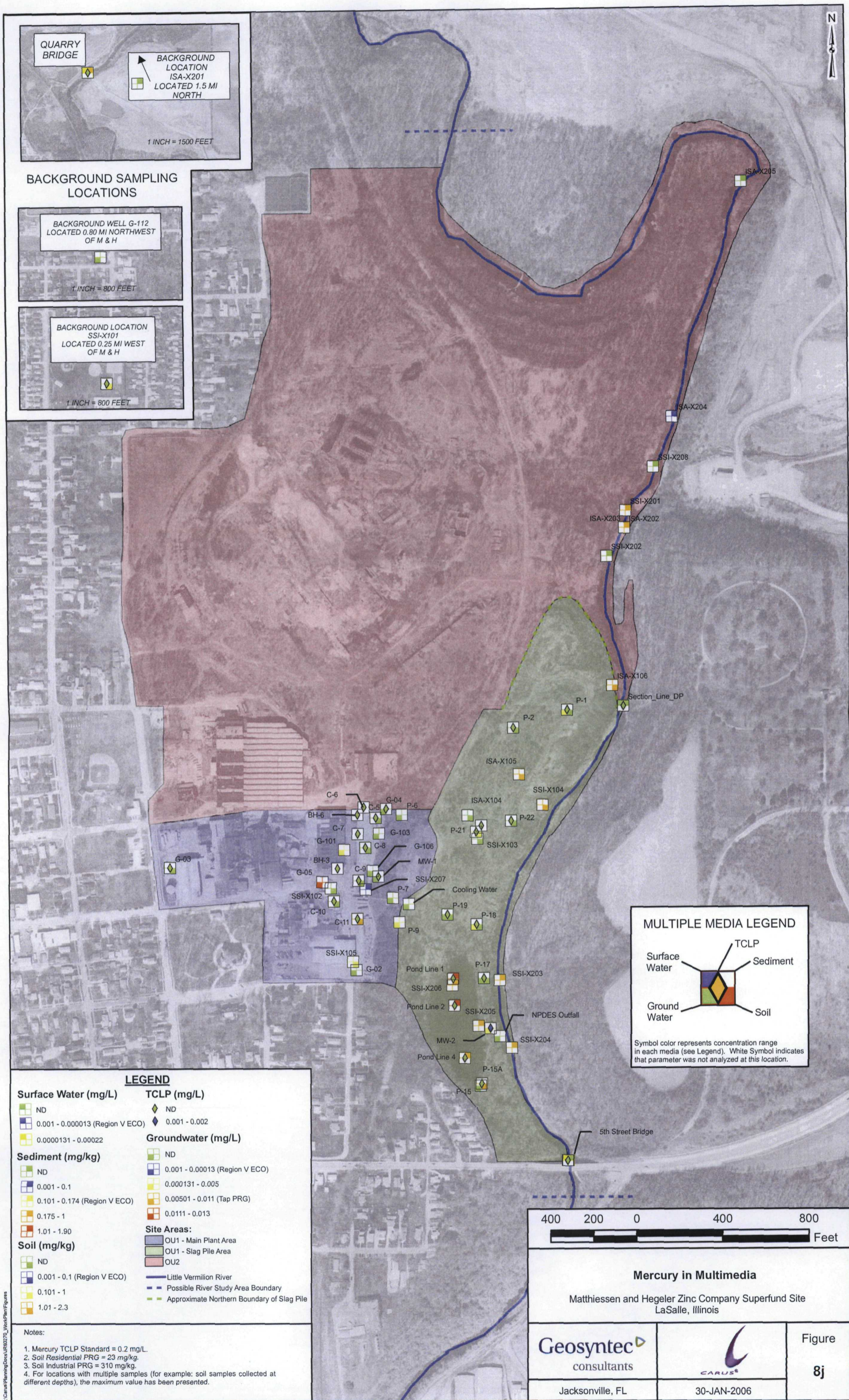


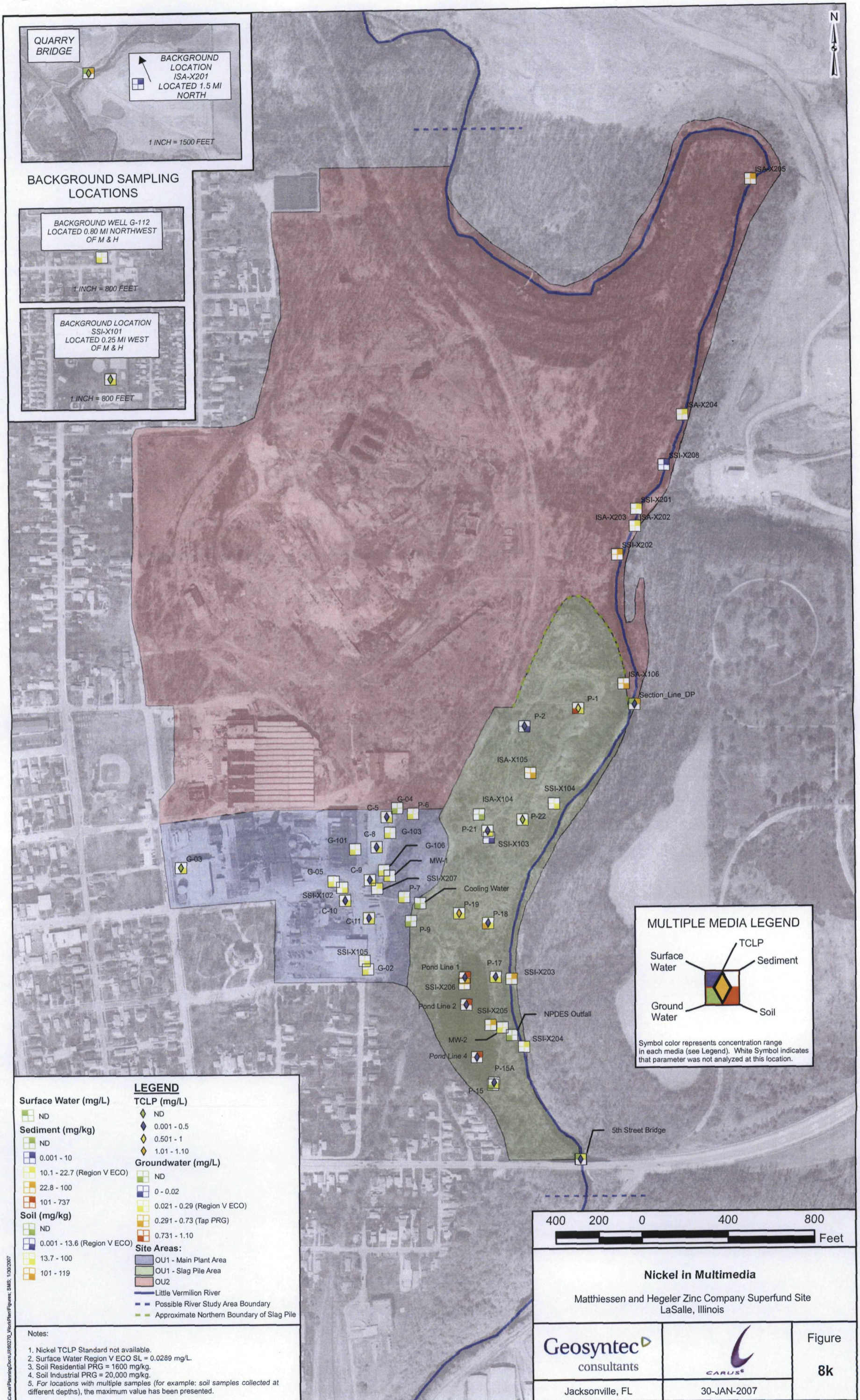


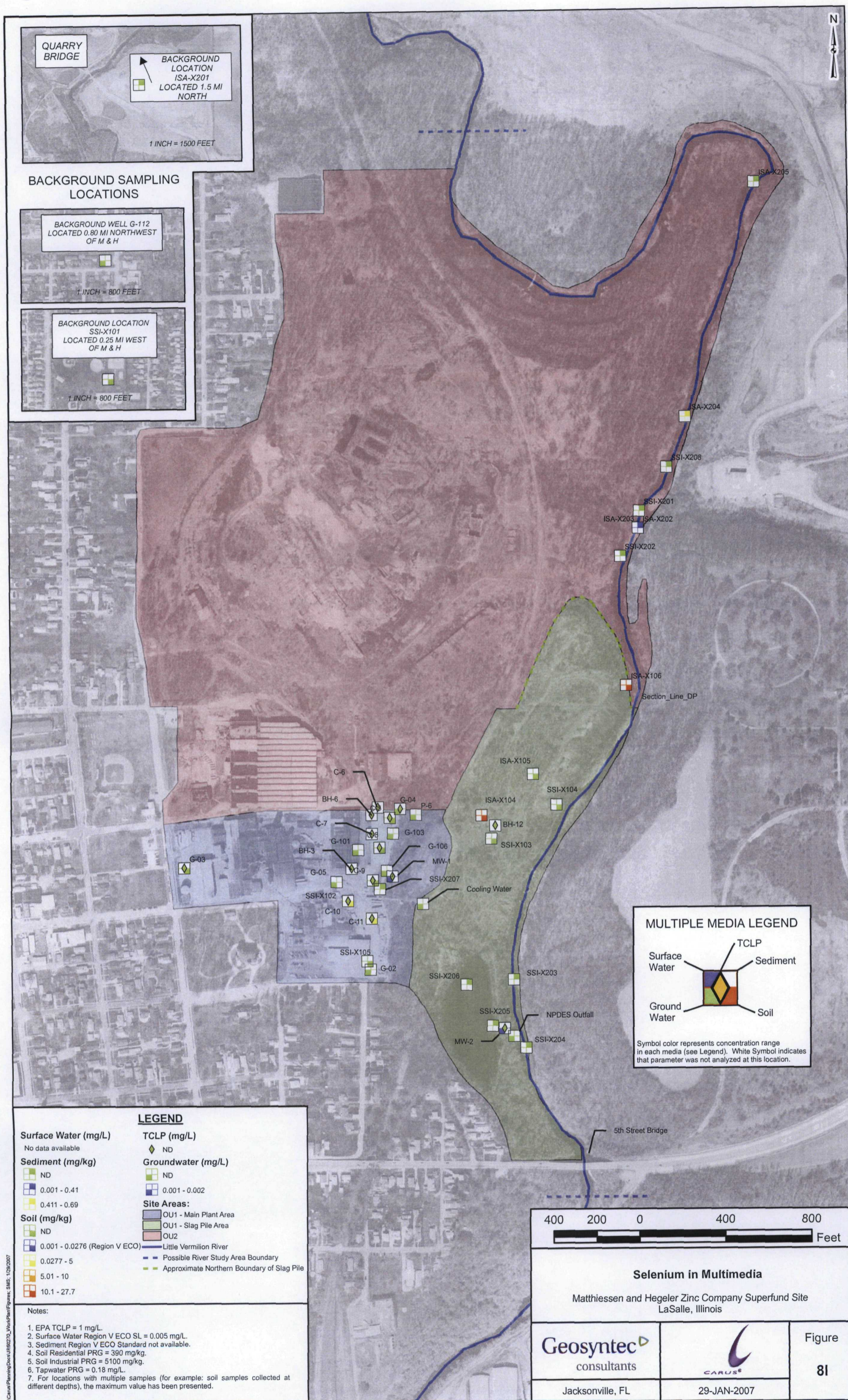


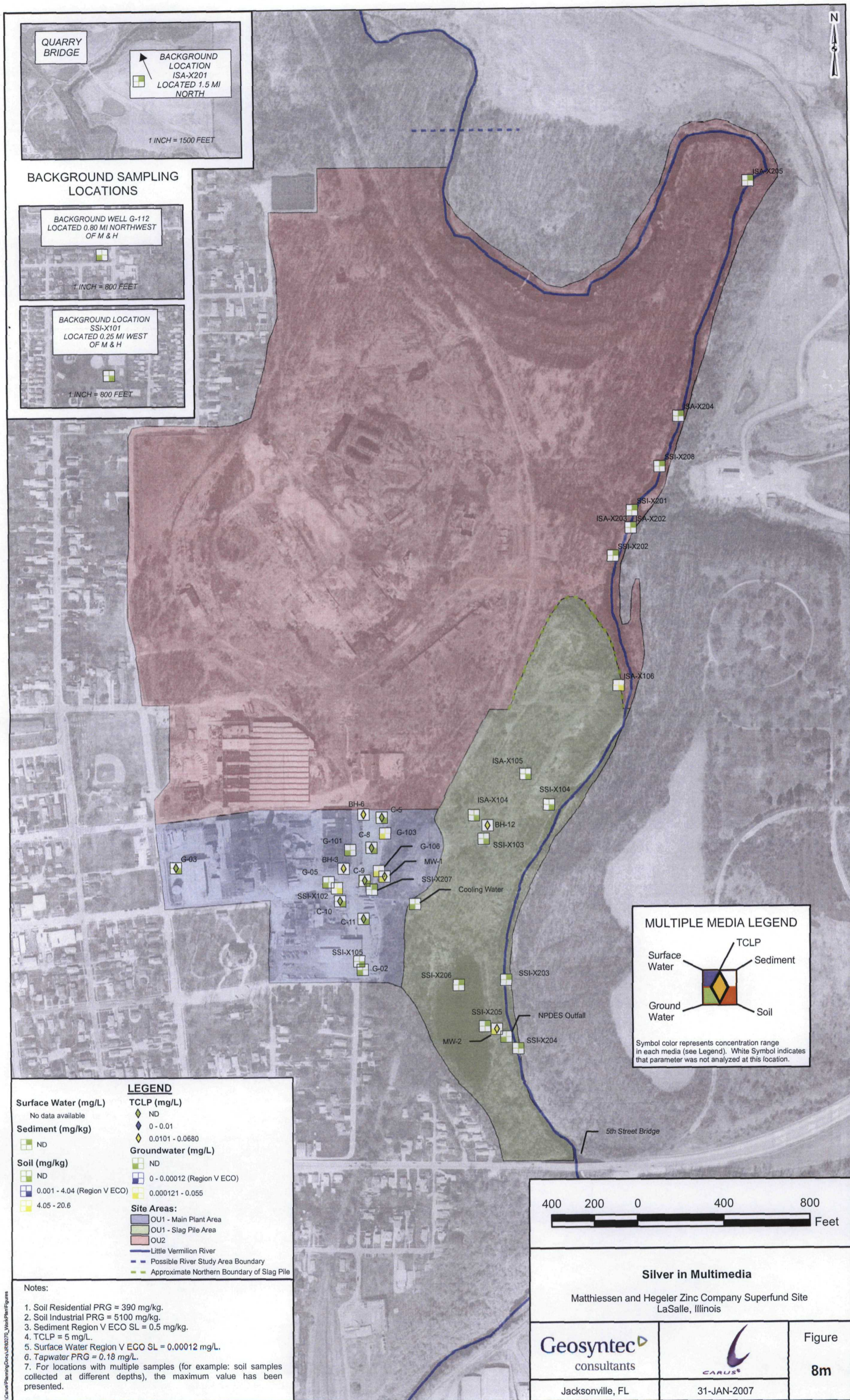


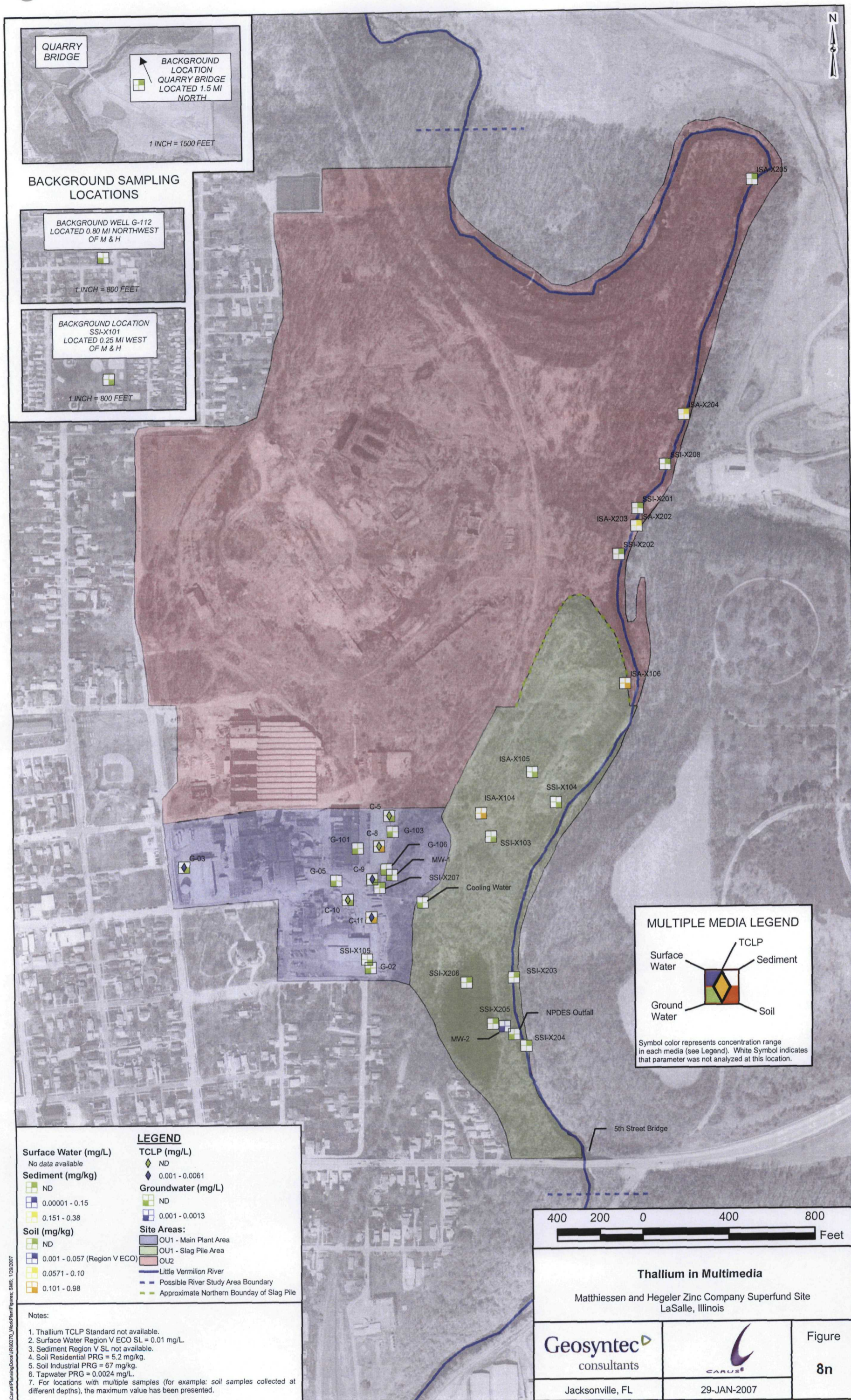












LEGEND

Surface Water (mg/L)	TCLP (mg/L)
No data available	ND
Sediment (mg/kg)	0.001 - 0.0061
ND	Groundwater (mg/L)
0.00001 - 0.15	ND
0.151 - 0.38	0.001 - 0.0013
Soil (mg/kg)	Site Areas:
ND	OU1 - Main Plant Area
0.001 - 0.057 (Region V ECO)	OU2 - Slag Pile Area
0.0571 - 0.10	OU3
0.101 - 0.98	Little Vermilion River
	Possible River Study Area Boundary
	Approximate Northern Boundary of Slag Pile

Notes:

1. Thallium TCLP Standard not available.
2. Surface Water Region V ECO SL = 0.01 mg/L.
3. Sediment Region V SL not available.
4. Soil Residential PRG = 5.2 mg/kg.
5. Soil Industrial PRG = 67 mg/kg.
6. Tapwater PRG = 0.0024 mg/L.
7. For locations with multiple samples (for example: soil samples collected at different depths), the maximum value has been presented.

MULTIPLE MEDIA LEGEND

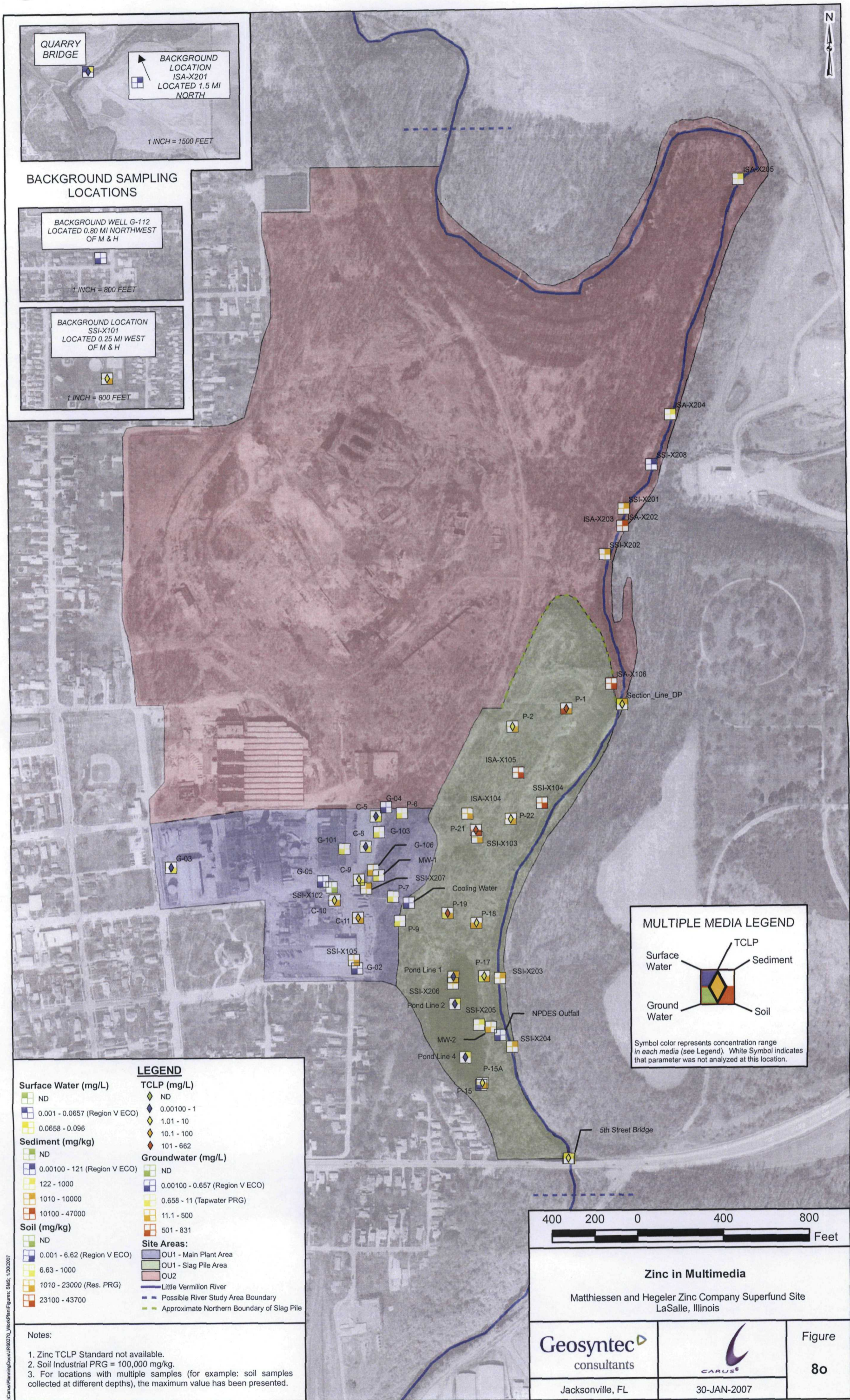
Symbol color represents concentration range in each media (see Legend). White Symbol indicates that parameter was not analyzed at this location.

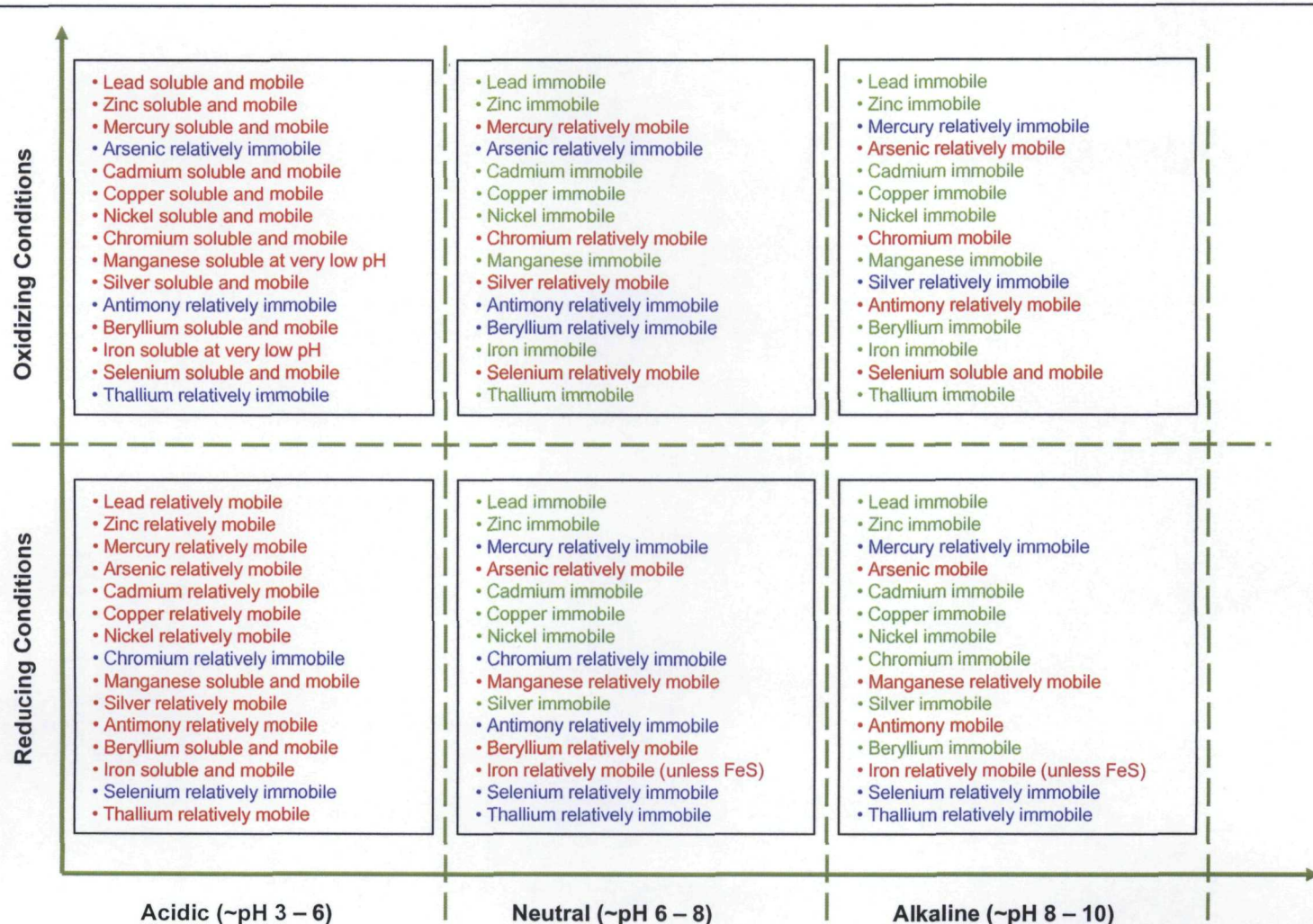
400 200 0 400 800 Feet

Thallium in Multimedia

Matthiessen and Hegeler Zinc Company Superfund Site
LaSalle, Illinois

Geosyntec consultants		Figure 8n
Jacksonville, FL	29-JAN-2007	





Generalized Effect of pH and Oxidation-Reduction Potential on Priority Metals Mobility

Matthiessen & Hegeler Zinc Company Superfund Site
LaSalle, Illinois

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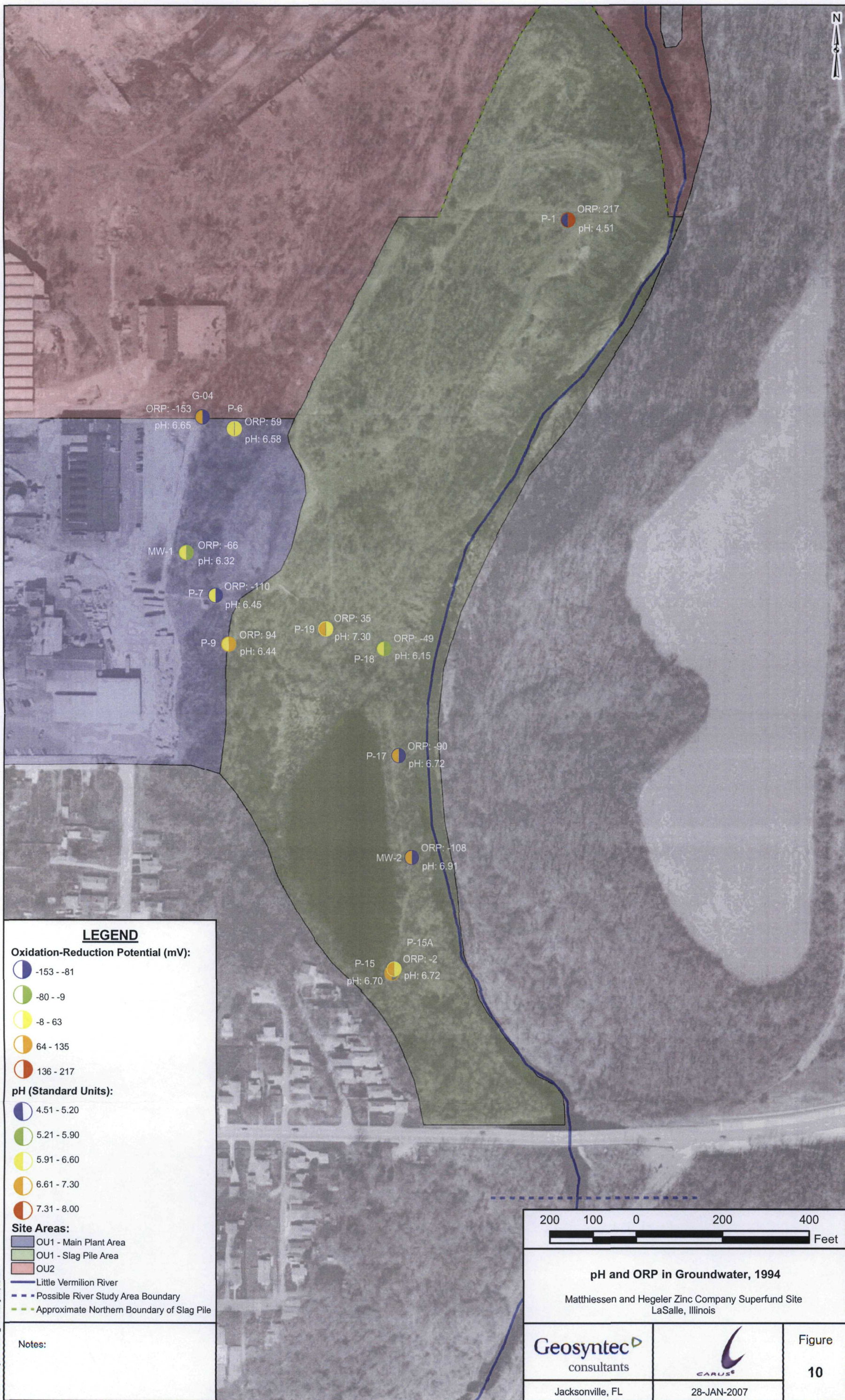


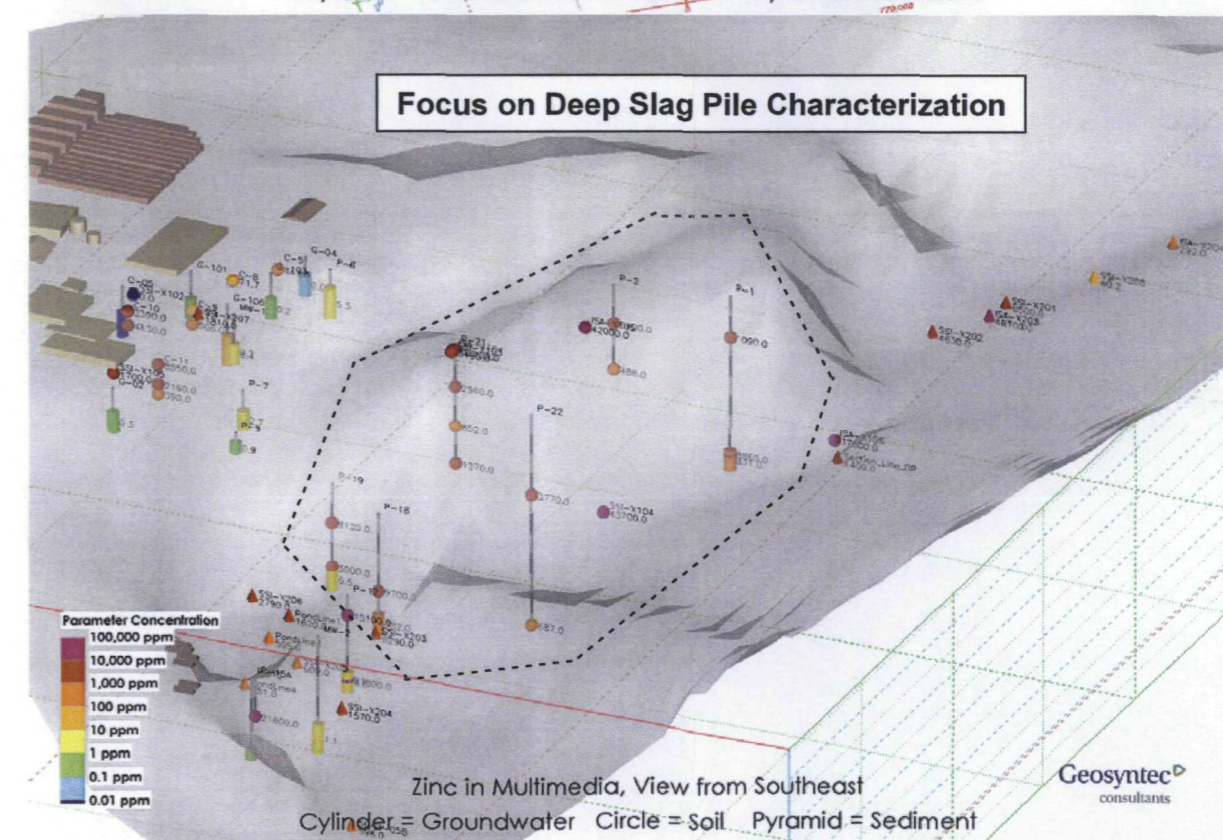
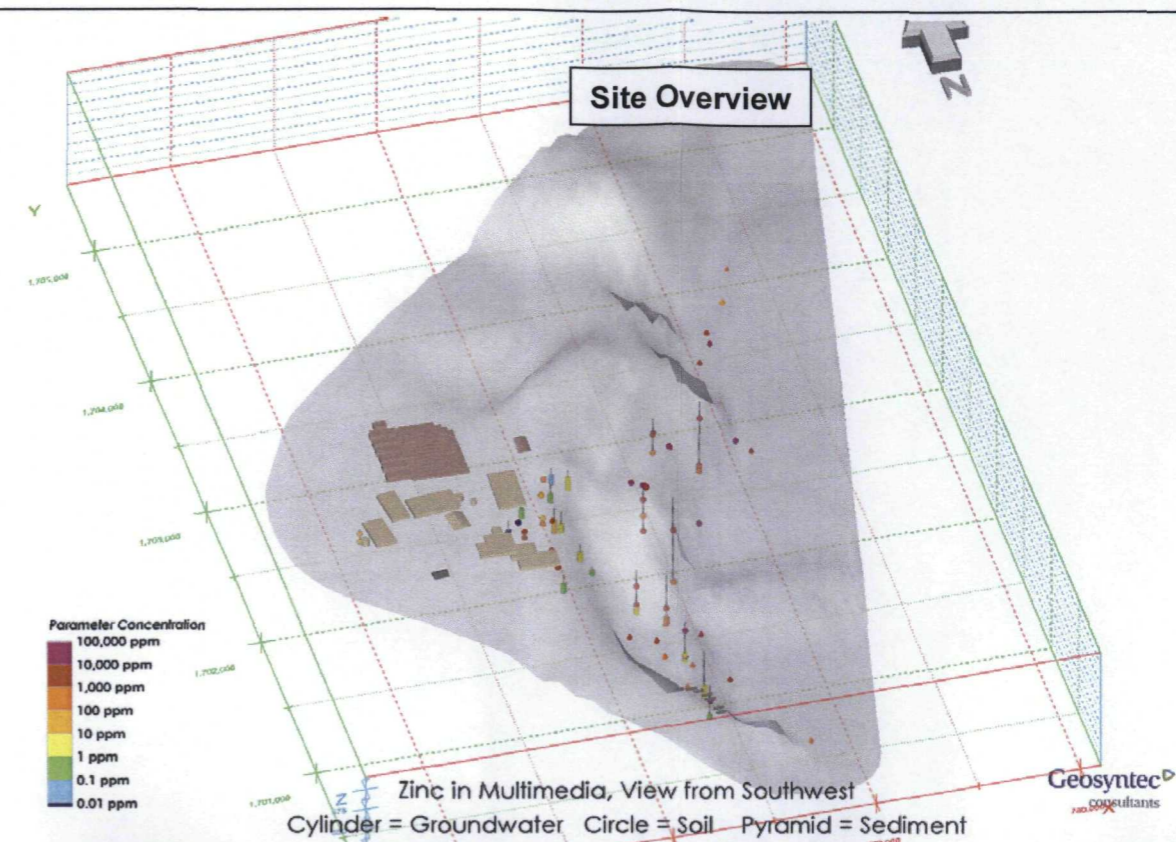
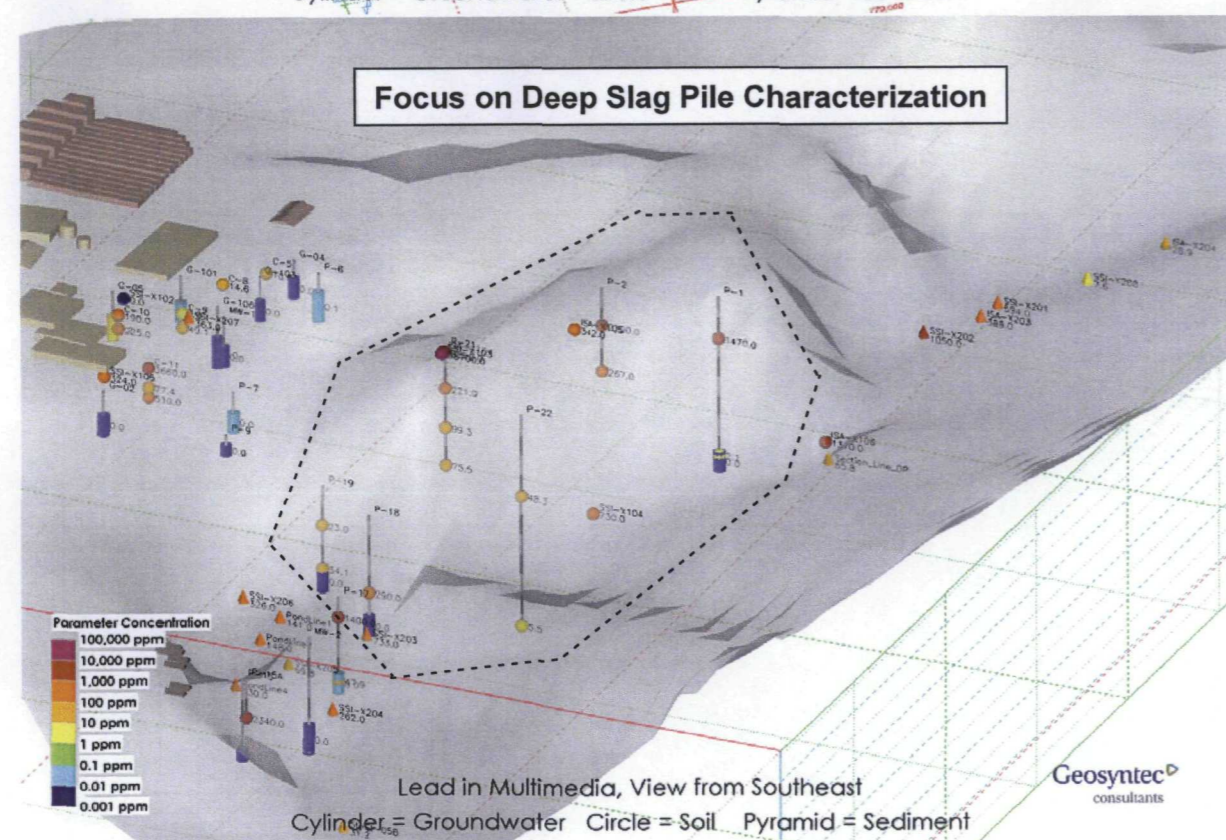
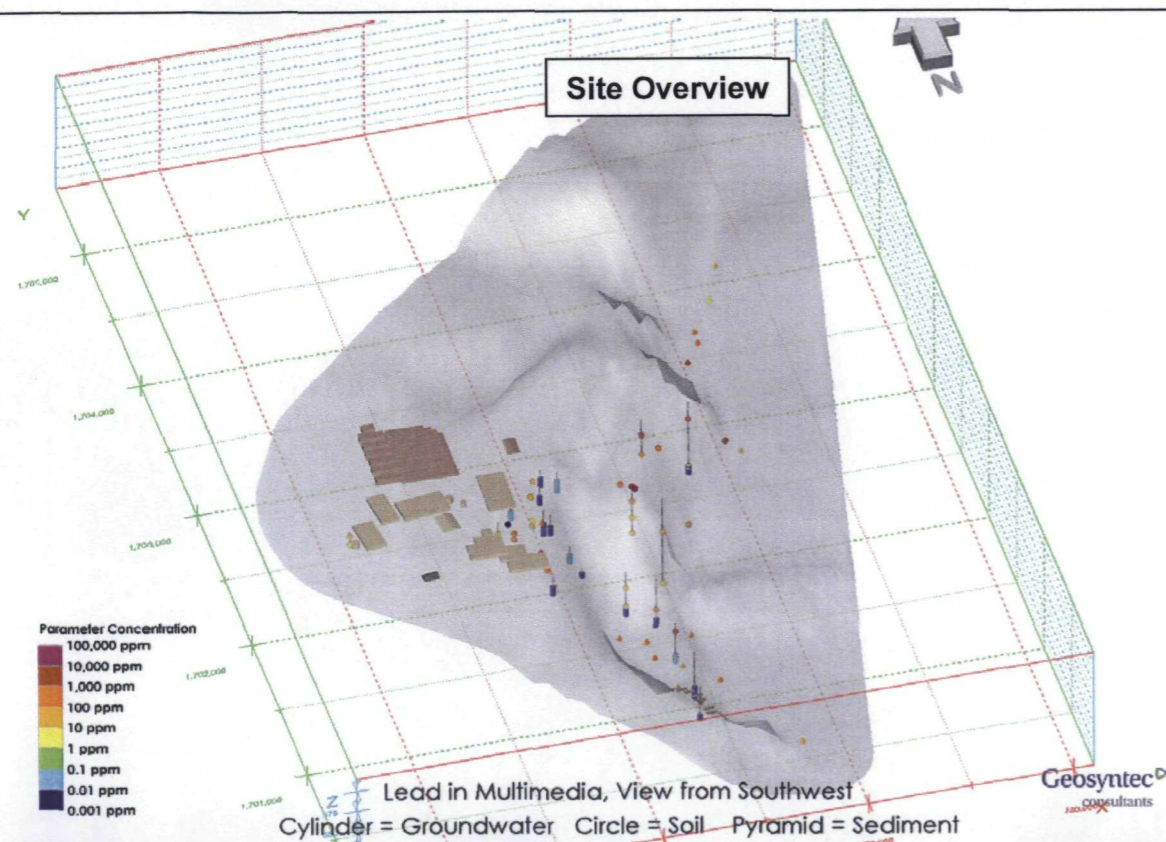
Atlanta, Georgia

29 JAN 2007

Figure

9





Three Dimensional Distribution Of Selected High Priority Metals

Matthiessen and Hegeler Zinc Company Superfund Site
LaSalle, Illinois

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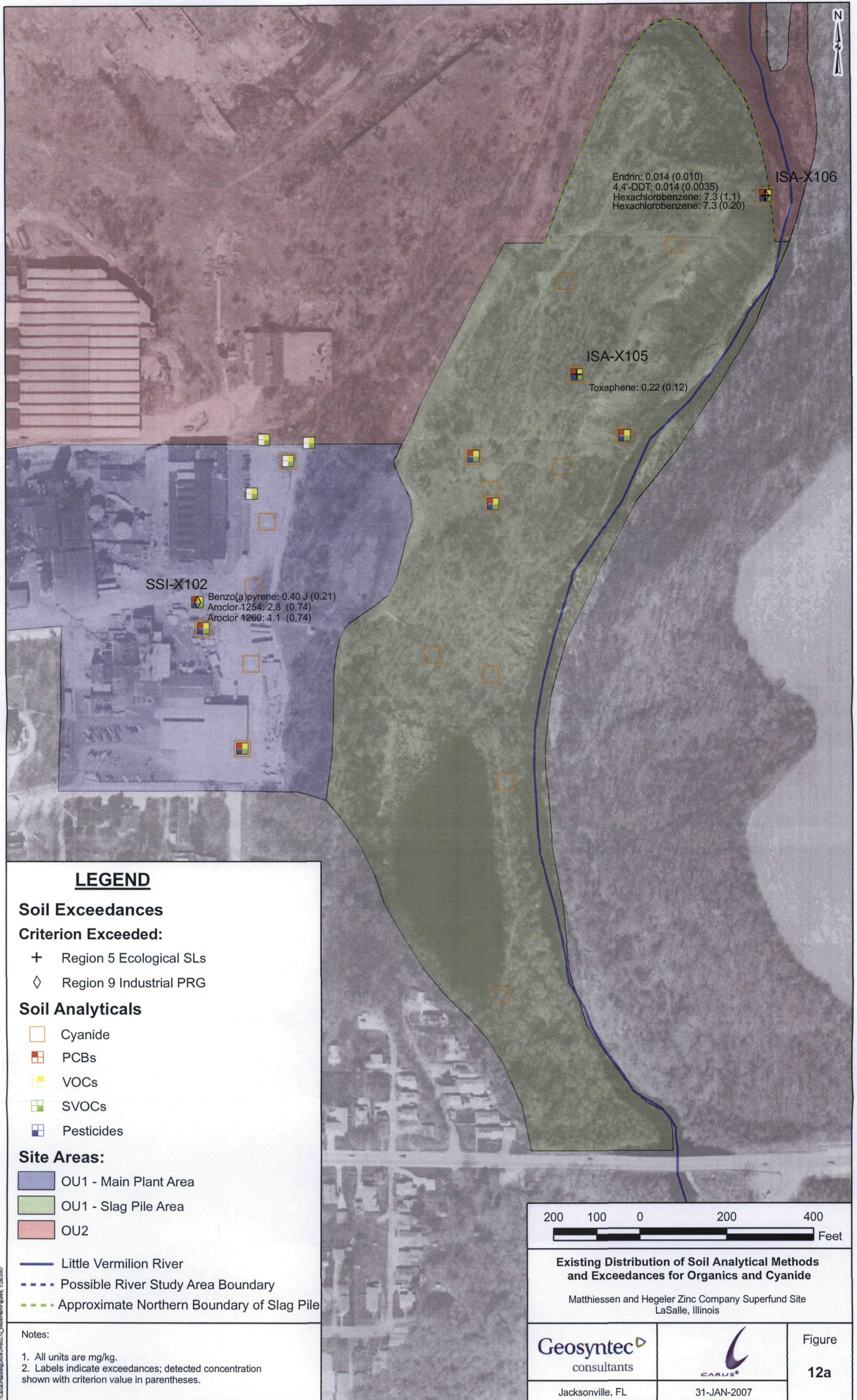
Jacksonville, FL

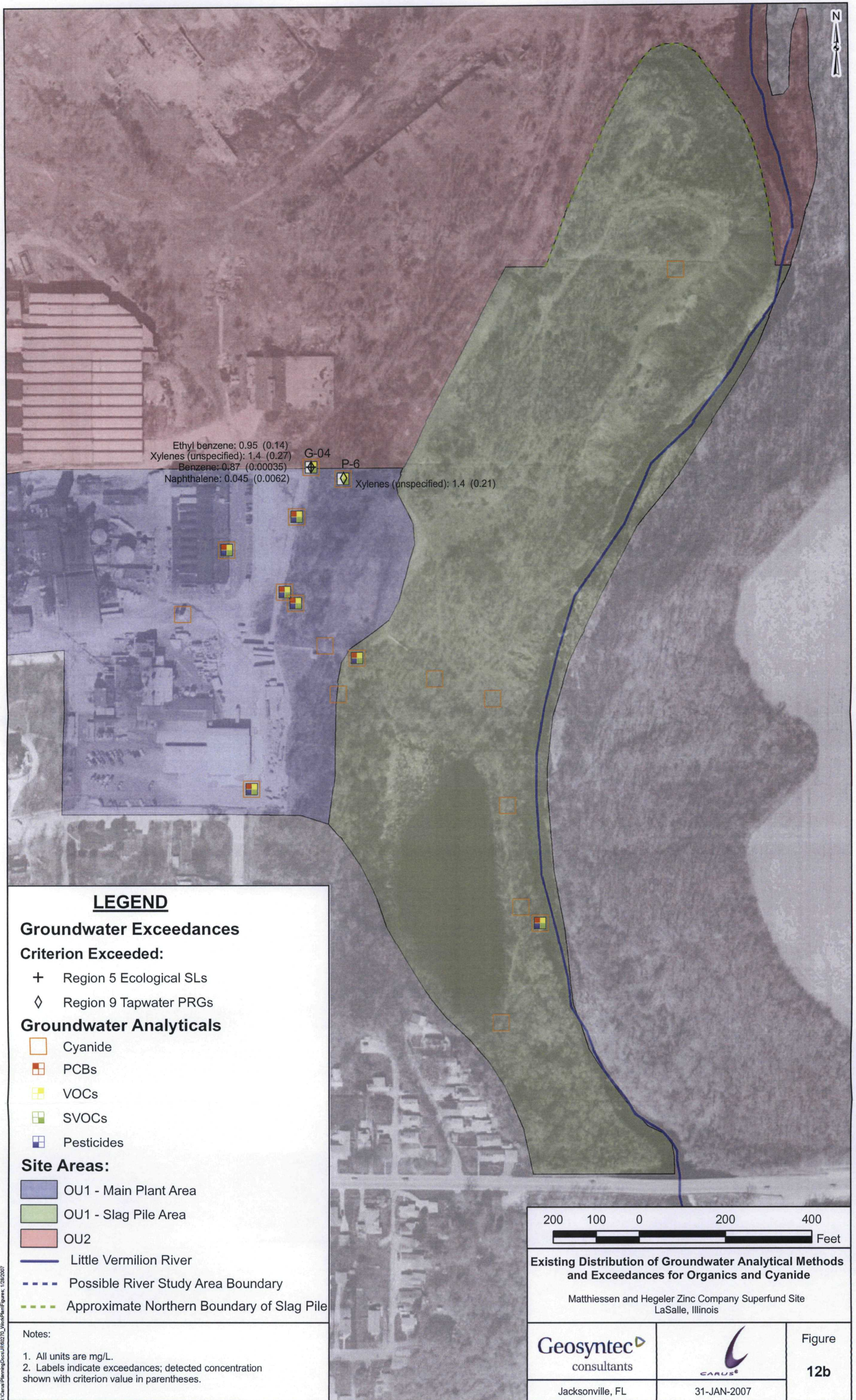
CARUS

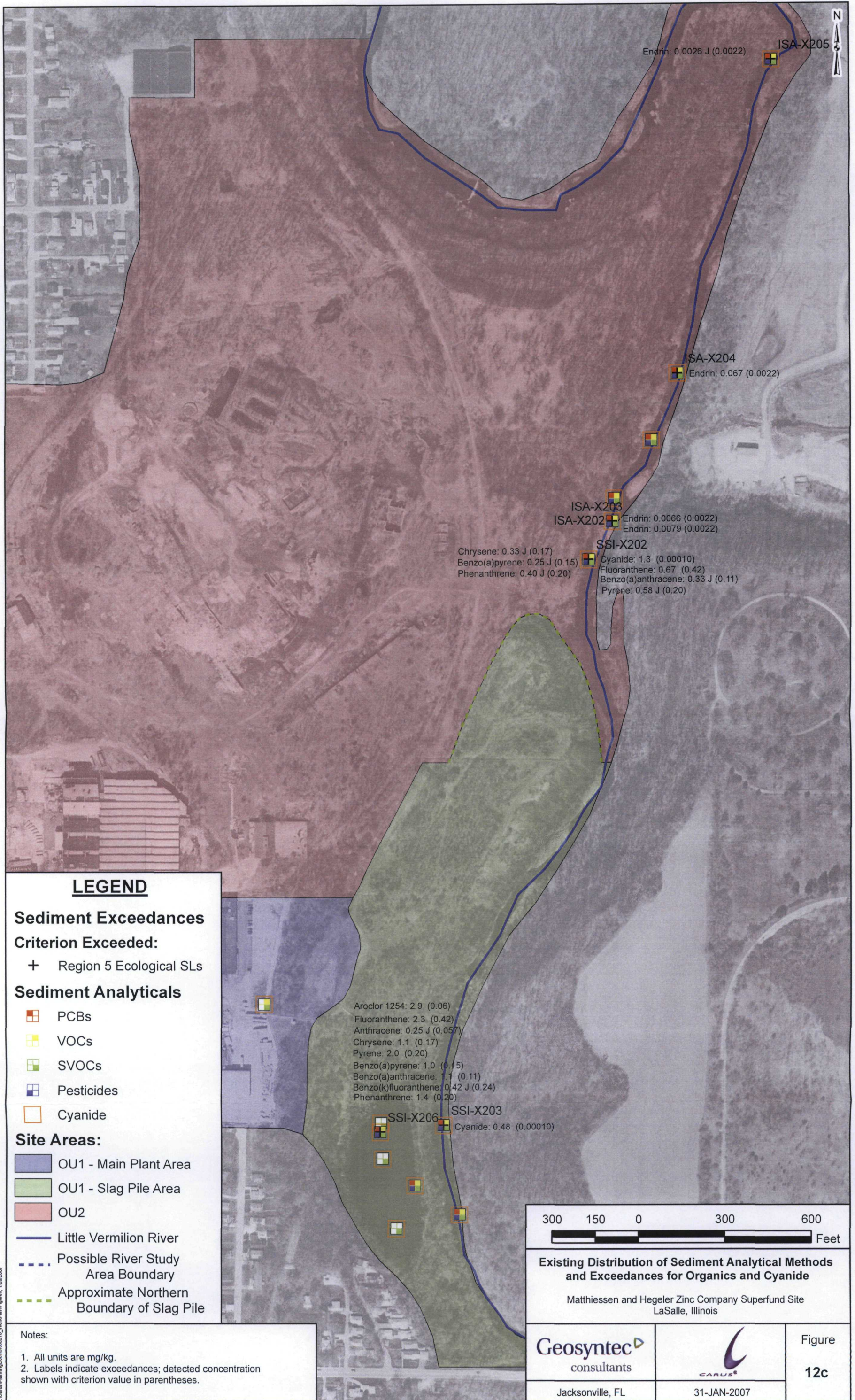
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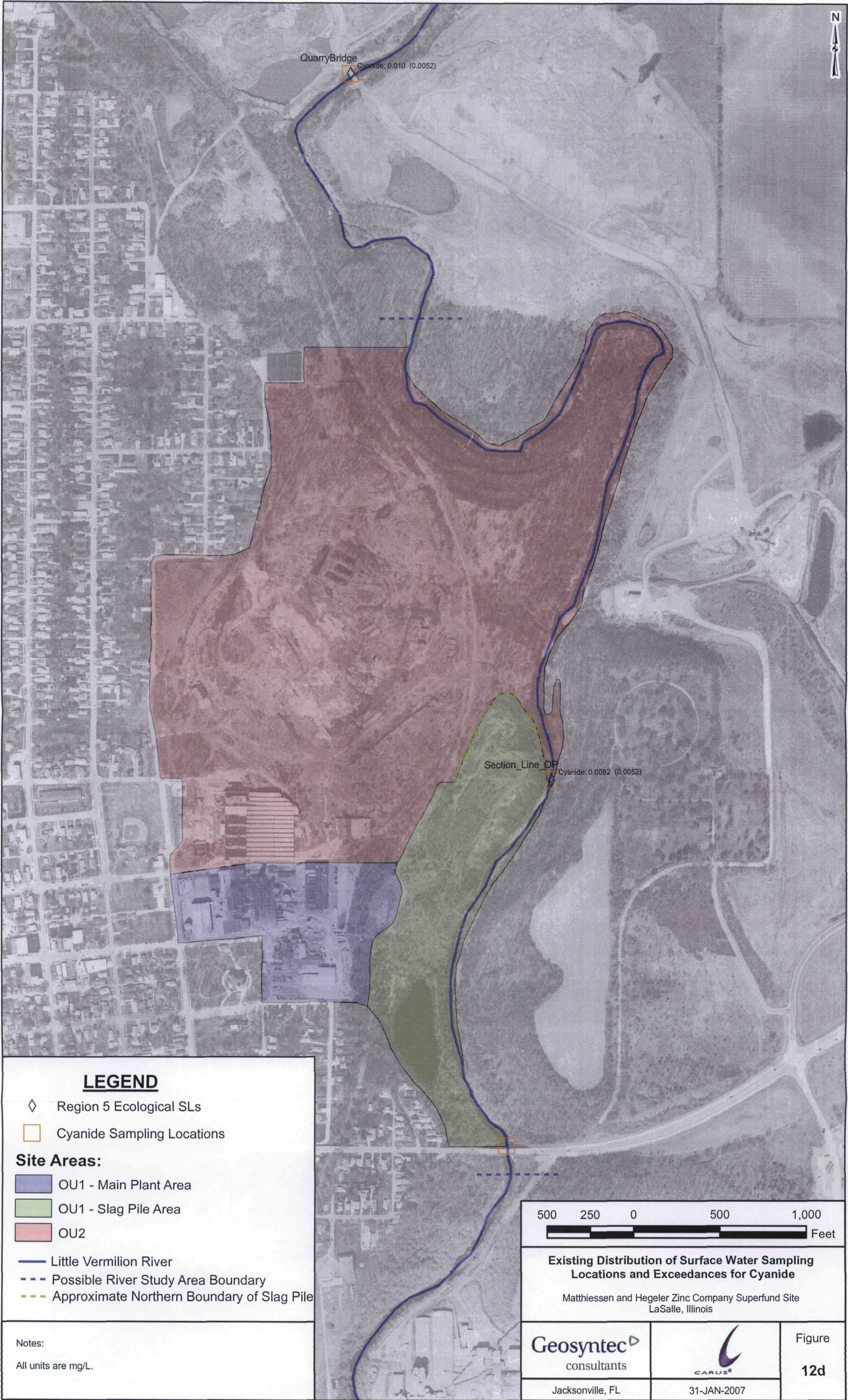
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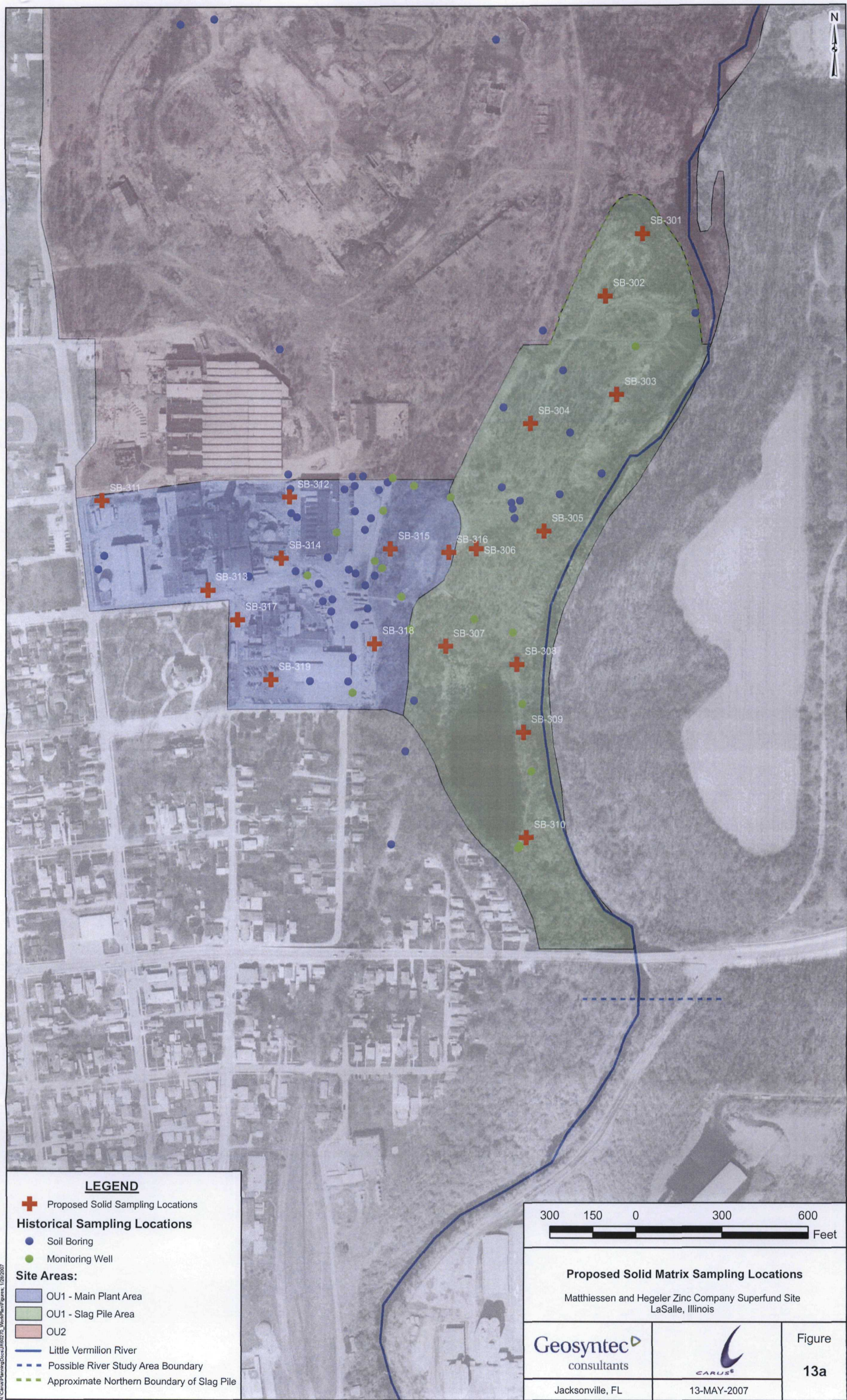
11











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LEGEND

+ Proposed Solid Sampling Locations

Historical Sampling Locations

● Soil Boring

● Monitoring Well

Site Areas:

■ OU1 - Main Plant Area

■ OU1 - Slag Pile Area

■ OU2

— Little Vermillion River

- - - Possible River Study Area Boundary

- - - Approximate Northern Boundary of Slag Pile

300 150 0 300 600
Feet

Proposed Solid Matrix Sampling Locations

Matthiessen and Hegeler Zinc Company Superfund Site
LaSalle, Illinois

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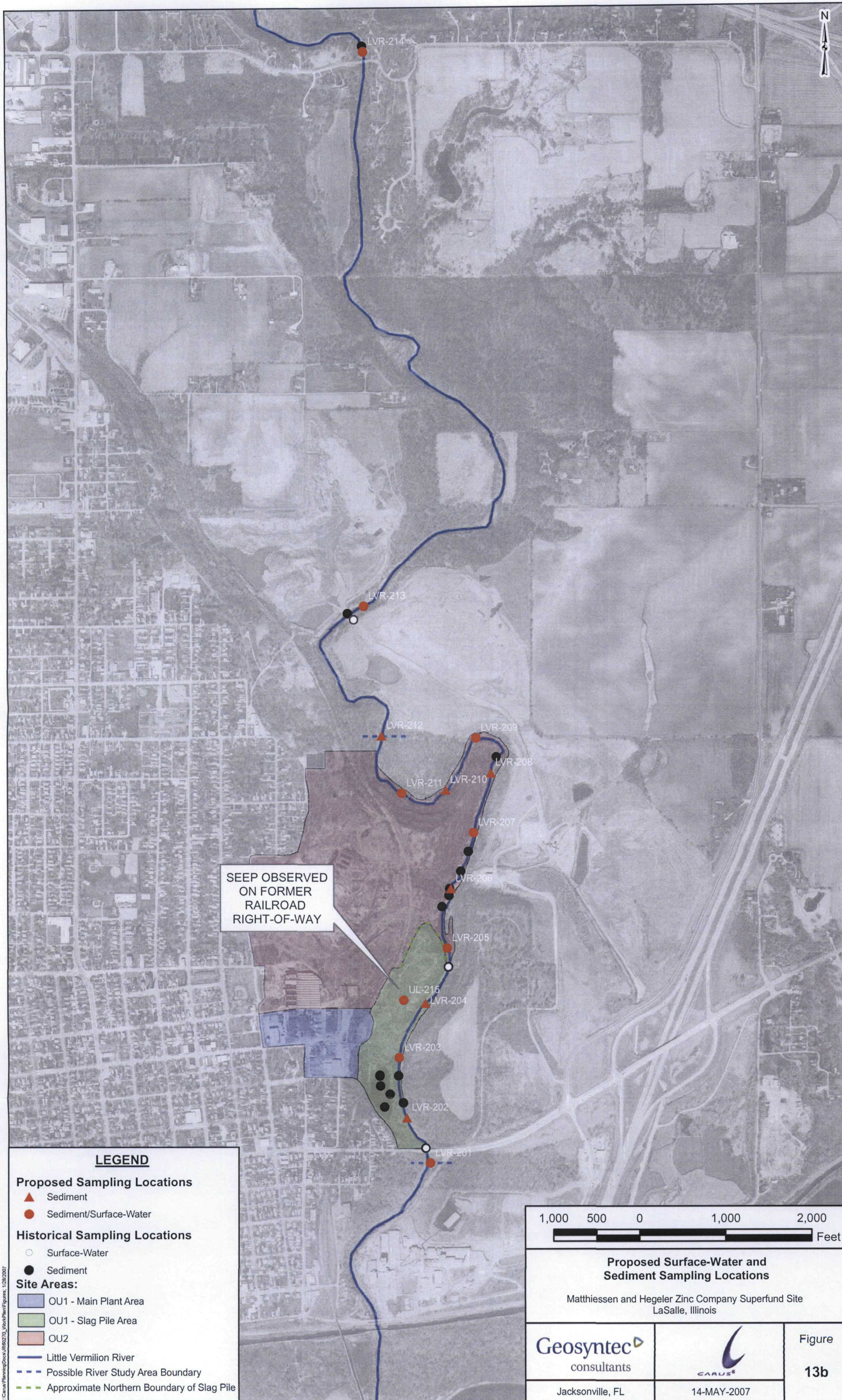
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13-MAY-2007

Figure

13a



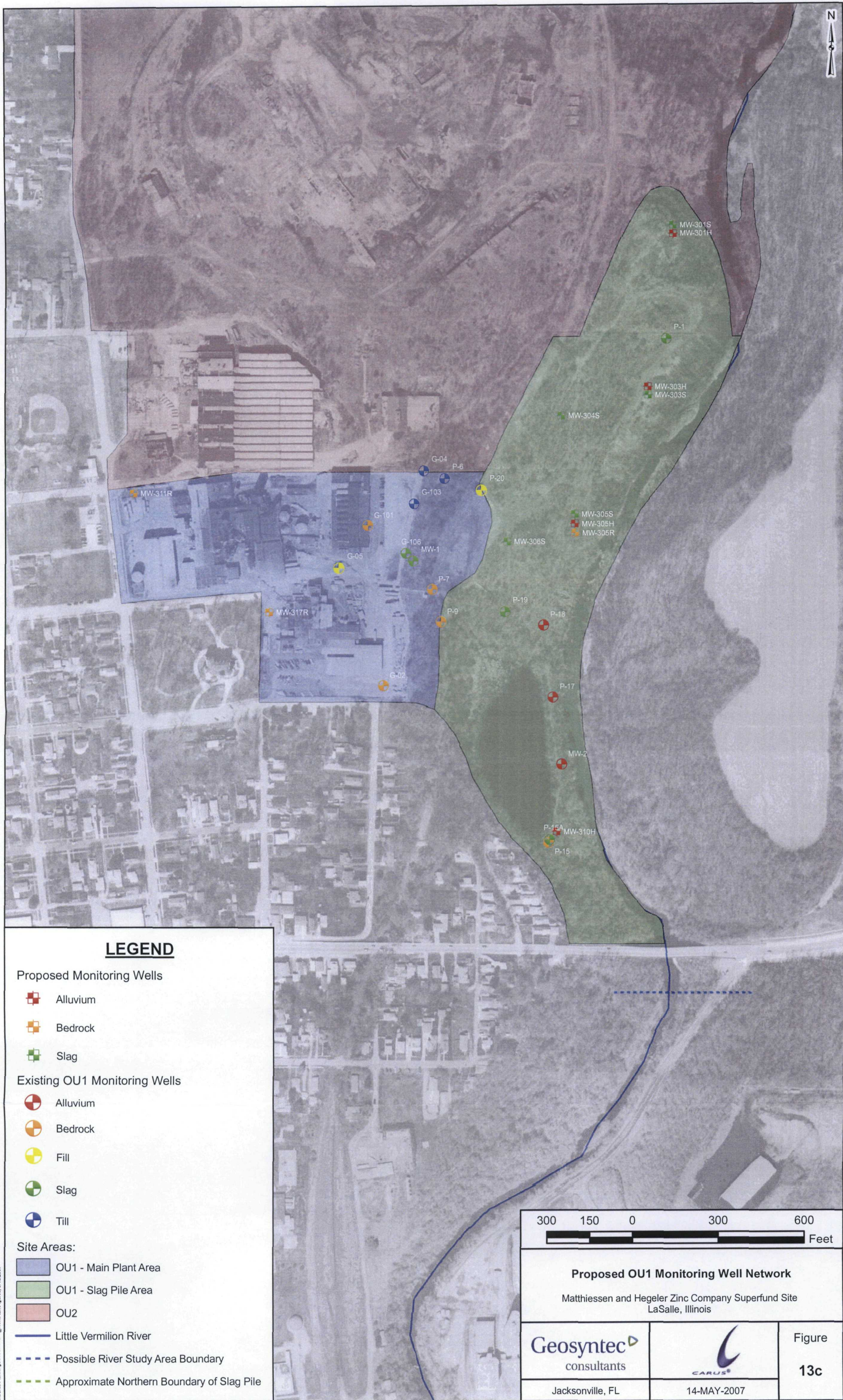
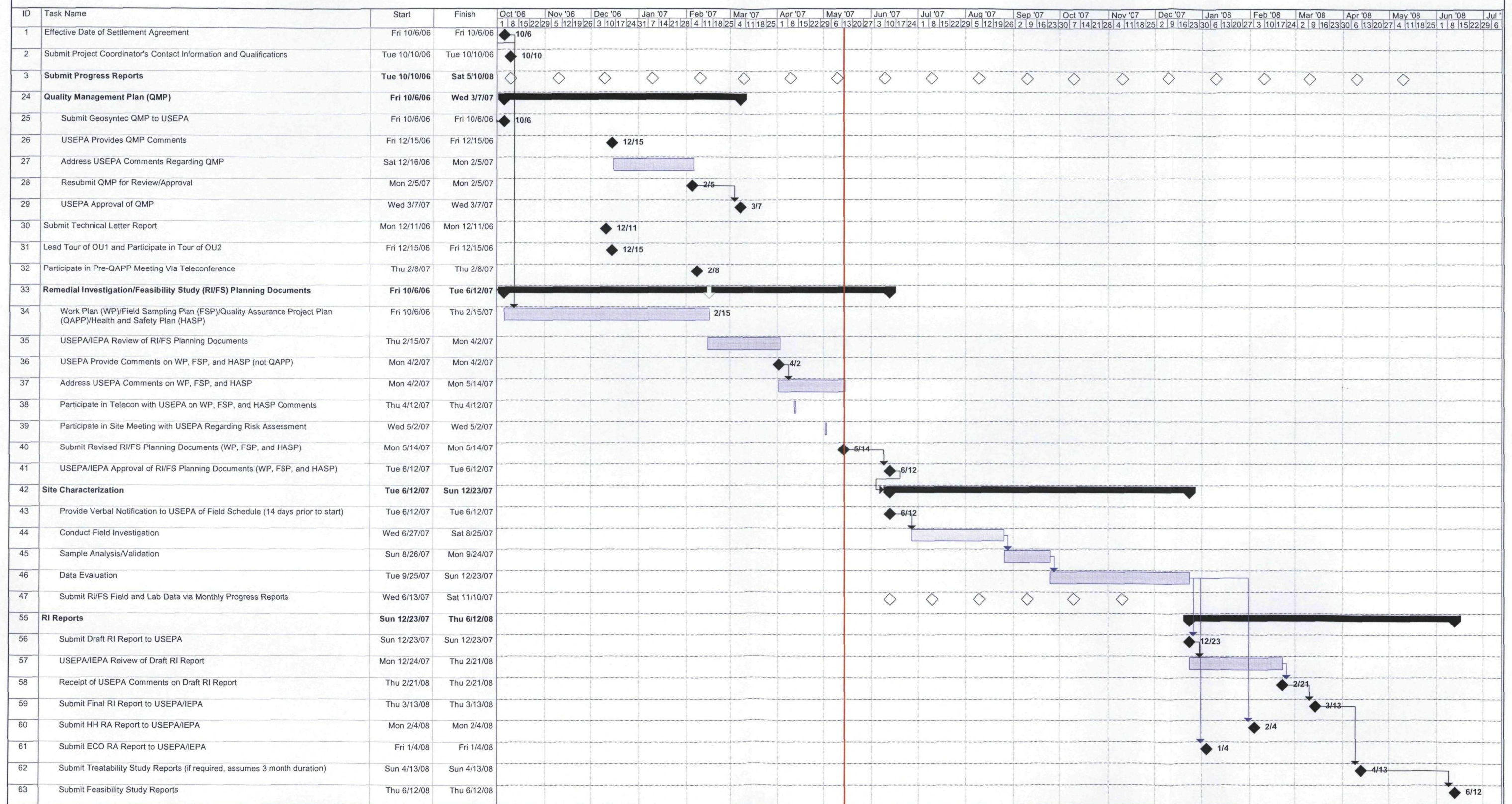


Figure 14. Project Schedule for RI/FS
Matthiessen and Hegeler Zinc Company Site
LaSalle, Illinois



Project: Project Schedule
Date: Mon 5/14/07

Task
Split

Progress
Milestone

Summary
Project Summary

External Tasks
External Milestone

Deadline

APPENDIX A

FSP

Prepared for:



**Carus Corporation and
Carus Chemical Company**

1500 Eighth Street
P.O. Box 1500
LaSalle, Illinois 61301-3500

FIELD SAMPLING PLAN REVISION 1

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

**MATTHIESSEN AND HEGELER ZINC COMPANY SITE
LASALLE, ILLINOIS**

Prepared by:

Geosyntec[®]
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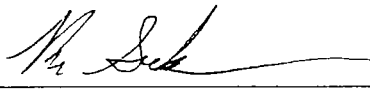
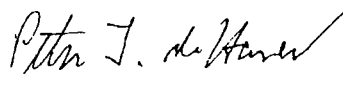
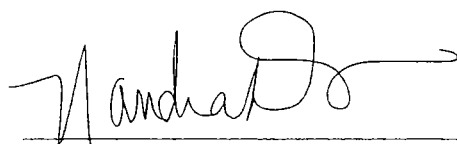
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2258 Riverside Avenue
Jacksonville, Florida 32204

Geosyntec Consultants Project Number FR1093

May 2007

This Field Sampling Plan for the Remedial Investigation/Feasibility Study at the Matthiessen and Hegeler Zinc Company Site in LaSalle, Illinois has been prepared by Geosyntec Consultants and reviewed by the following:

Prepared by:		05/10/07
	Raphael A. Siebenmann, E.I.T	Date
Reviewed by:		05/10/07
	Peter J. de Haven. P.E. Data Management Lead	Date
		05/14/07
	Nandra D. Weeks, P.E. Project Manager	Date

Brief Description of Amendment	Amendment Date

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1 Terms of Reference.....	1
1.2 FSP Scope	2
1.3 Site History and Background	6
1.3.1 Site Location	6
1.3.2 Site Operations History.....	7
1.3.3 Site Description.....	8
1.4 Understanding of Contaminant Characterization.....	9
1.4.1 Chronology and Rationale of Historical Investigations	9
1.4.2 Summary of Investigative Findings	11
1.5 Potential Sources of Contamination.....	13
1.6 Data Gaps.....	14
1.6.1 Introduction	14
1.6.2 Physical Characterization Needs	14
1.6.3 Nature and Extent of Contamination.....	14
1.6.4 Fate, Transport, and Risk Mechanisms	16
1.6.5 Remedy Evaluation Data.....	17
1.7 Sampling Objectives	17
2. FIELD ACTIVITIES	19
2.1 Mobilization and Site Access.....	19
2.1.1 Pre-Investigation Activities.....	19
2.1.2 Site Access Control	19
2.1.3 Field Standard Operating Procedures.....	20

TABLE OF CONTENTS (continued)

2.2	Solid Matrix Investigation	21
2.2.1	Introduction and Sampling Rationale.....	21
2.2.2	Sampling Details	24
2.2.3	Solid Sample Collection Procedures.....	26
2.2.3.1	Sampling Equipment	26
2.2.3.2	Logging and Sample Collection	26
2.2.3.3	Sample Containerization	26
2.2.4	Sample Handling and Analysis	26
2.3	Surface-Water and Sediment Characterization Program	27
2.3.1	Introduction and Sampling Rationale.....	27
2.3.2	River Characterization Program.....	29
2.3.2.1	Physical Characterization	29
2.3.2.2	Sample Location and Frequency of River Samples	29
2.3.3	Upland Sediment and Surface-Water Samples	30
2.3.4	Surface-Water and Sediment Sample Collection Procedures	30
2.3.5	Sample Handling and Analysis	31
2.4	Groundwater Investigation.....	31
2.4.1	Introduction and Sampling Rationale.....	31
2.4.2	Monitoring Well Network.....	34
2.4.3	Well Reconnaissance and Rehabilitation.....	35
2.4.4	Monitoring Well Installation.....	35
2.4.5	Monitoring Well Development	36
2.4.6	Monitoring Well/Borehole Abandonment	36
2.4.7	Groundwater Sample Collection Procedures	37

TABLE OF CONTENTS (continued)

2.4.7.1	Sampling Equipment	37
2.4.7.2	Sample Collection	37
2.4.7.3	Sample Containerization	38
2.4.8	Sample Handling and Analysis	38
2.4.9	Hydraulic Testing.....	38
2.5	Habitat Characterization	39
2.6	Ambient Air Sampling.....	40
2.6.1	Sample Location and Frequency.....	40
2.6.2	Ambient Air Sample Collection Procedures.....	41
2.6.3	Sample Handling and Analysis	41
2.7	Field Quality Assurance/Quality Control Samples.....	41
2.7.1	Trip Blanks.....	42
2.7.2	Equipment Rinsate Blanks	42
2.7.3	Field Blanks	43
2.7.4	Duplicate Samples.....	43
2.7.5	Matrix Spike/Matrix Spike Duplicate Samples.....	43
2.8	Field Surveying.....	43
2.8.1	Horizontal and Vertical Control.....	43
2.8.2	Data Acquisition.....	44
3.	DOCUMENTATION, SAMPLE PACKING, AND SHIPPING	45
3.1	Field Documentation.....	45
3.1.1	Details of Log Book Use	46
3.1.2	Field Forms.....	47

TABLE OF CONTENTS (continued)

3.2	Sample Nomenclature	48
3.2.1	Field Sample Nomenclature	48
3.2.2	Quality Assurance/Quality Control Sample Nomenclature.....	50
3.3	Sample Packing and Shipping – Field Procedures	51
3.3.1	Hold Times	51
3.3.2	Sample Custody	51
3.3.3	Chain-of-Custody Record	52
3.3.4	Sample Packing and Shipping	54
4.	DECONTAMINATION	55
4.1	Standard Procedures.....	55
4.2	Sampling Equipment Decontamination Procedures	55
4.3	Heavy Equipment.....	56
4.4	Persistent Contamination	56
4.5	Disposal of Contaminated Materials.....	57
5.	MANAGEMENT OF INVESTIGATION-DERIVED WASTES.....	58
5.1	Identification of Investigation-Derived Waste Streams.....	58
5.2	Drilling Spoils	58
5.3	Well Development and Purge Water	59
5.4	Decontamination Wastes	59
5.5	Personal Protective Equipment	60
6.	SCHEDULE	61

TABLE OF CONTENTS (continued)

LIST OF TABLES

Table 1	Sample IDs, Locations, Depths, and Analyses for Solid, River, and Groundwater Sampling
Table 2	Summary of Container, Preservation, and Hold Requirements for Samples
Table 3	Inventory of Existing Monitoring Wells and Piezometers
Table 4	Action Levels for Metal Chemicals of Potential Concern in Ambient Air Samples
Table 5	Field Quality Control Samples

LIST OF FIGURES

Figure 1	Approximate Boundary of Matthiessen and Hegeler Zinc Company Superfund Site
Figure 2	Proposed Solid Matrix Sampling Locations
Figure 3	Proposed Surface-Water and Sediment Sampling Locations
Figure 4	Proposed Groundwater Sampling Locations

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS

ACGIH	American Conference of Industrial Hygienists
ARARs	Applicable or Relevant and Appropriate Requirements
ASAO	Administrative Settlement Agreement and Order on Consent
AVS/SEM	Acid Volatile Sulfide/Simultaneously Extracted Metals
BERA	Baseline Ecological Risk Assessment
BLS	Below Land Surface
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
CAS	Columbia Analytical Services
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation and Liability Information System
COPC	Chemical of Potential Concern
CFR	Code of Federal Regulation
CSM	Conceptual Site Model
DO	Dissolved Oxygen
DOT	Department of Transportation
DPT	Direct-Push Technology
DQO	Data Quality Objective
EZ	Exclusion Zone
FS	Feasibility Study
FSP	Field Sampling Plan
Geosyntec	Geosyntec Consultants
GPS	Global Positioning System
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HDPE	High-Density Polyethylene
HHRA	Human Health Risk Assessment
HRS	Hazard Ranking System
HSA	Hollow-Stem Auger

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS (continued)

IAC	Illinois Administrative Code
ICRR	Illinois Central Railroad
ID	Identification
IDW	Investigation-Derived Waste
IEPA	Illinois Environmental Protection Agency
LPM	Laboratory Project Manager
M&H	Matthiessen and Hegeler
MAGI	Materials Analysis Group, Inc.
MS	Matrix Spike
MSD	Matrix Spike Duplicate
MSL	Mean Sea Level
NAD	North American Datum
NIOSH	National Institute for Occupational Safety and Health
NGVD	National Geodetic Vertical Datum
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NTU	Nephelometric Turbidity Unit
ORP	Oxidation-Reduction Potential
OU1	Operable Unit 1
OU2	Operable Unit 2
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PID	Photo-Ionization Detector
PPE	Personal Protective Equipment
PRP	Potentially Responsible Party
PSI	Preliminary Site Investigation
PVC	Polyvinyl Chloride
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control

TABLE OF CONTENTS (continued)

LIST OF ACRONYMS (continued)

RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SEP	Sequential Extraction Procedure
SHSO	Site Health and Safety Officer
SLERA	Screening Level Ecological Risk Assessment
SOP	Standard Operating Procedure
SPLP	Synthetic Precipitation Leaching Procedure
SSI	Screening Site Inspection
SVOC	Semi-Volatile Organic Compound
TAL	Target Analyte List
TCLP	Toxicity Characteristic Leaching Procedure
TLR	Technical Letter Report
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
USCS	Unified Soil Classification System
VOC	Volatile Organic Compound
XRD	X-Ray Diffraction

1. INTRODUCTION

1.1 Terms of Reference

This Field Sampling Plan (FSP) has been prepared as part of the Remedial Investigation/Feasibility Study (RI/FS) for the Matthiessen and Hegeler (M&H) Zinc Company Site (Site) located in LaSalle, Illinois. The RI/FS is required by an Administrative Settlement Agreement and Order on Consent (ASAOC), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Docket No.V-W-06-C-856, dated 6 October 2006, between United States Environmental Protection Agency (USEPA) Region V, Carus Corporation, and Carus Chemical Company (Carus), pursuant to the CERCLA. In preparing the Technical Letter Report (TLR) submitted to USEPA in December 2006 pursuant to the ASAOC, Geosyntec provided a description of the data gaps to be addressed to meet the objectives of the RI. This FSP addresses the additional data and evaluation needed in order to evaluate the extent of hazardous substances, pollutants, or contaminants at Operable Unit 1 (OU1) and nearby areas (Section 1.6 of the FSP). During the course of the RI/FS, environmental samples will be collected to supplement the existing data to: (i) characterize the nature and extent of any contamination stemming from past site practices, as well as the risks to human health and the environment stemming therefrom; and (ii) develop and evaluate remedial alternatives for the Site.

This FSP has been prepared as a stand-alone document and includes sufficient background information to help the field staff understand the purpose of the investigations, as well as rationale for sampling locations. The FSP provides details for field sampling locations and procedures and will be most frequently used by field staff on-site. The majority of the activities proposed herein will be coordinated with field efforts planned by SulTRAC, USEPA's contractor for Operable Unit 2 (OU2).

This FSP is one of four RI/FS Planning Documents submitted concurrently in fulfillment of Task 1.3 of the ASAOC. Other, concurrently submitted planning documents include the following:

- RI/FS Work Plan, which provides an overview of the OU1 background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;

- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization (Appendix B of the RI/FS Work Plan); and
- Health and Safety Plan (HASP), which identifies physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards (Appendix C of the RI/FS Work Plan).

Standard Operating Procedures (SOPs), which provide the protocols for field operations (Appendix D of the RI/FS Work Plan), are also submitted concurrently, as well as historical data on disk (Appendix E of the RI/FS Work Plan).

1.2 FSP Scope

Section IV of Appendix A of the ASAOC requires that the FSP include multiple environmental programs, as listed below in bold font. The objective of each environmental program, as provided in Section IV of Appendix A, is underlined, and the Respondent's overall approach follows. The initial phase of the RI is designed to meet most of the objectives required by the environmental programs. In some cases, certain elements listed in the ASAOC for consideration are not required to meet the overall objectives. For example, limited physical characterization (drilling and trenching) will accomplish the level of delineation required during the RI to delineate the slag in OU1 (hence, an extensive geophysical investigation is not warranted). In some cases, the objectives will be met through an iterative process. Two examples of an iterative process include: (i) river characterization where physical characterization and limited analytical testing of surface water and sediments will be accomplished first, followed by additional analytical testing based on the results of the initial RI efforts; and (ii) the ecological risk assessment process, as provided for in USEPA guidance, such that a habitat characterization will first be conducted to determine appropriate biota to be sampled during later stages of the risk assessment process. The RI provides for all environmental programs listed in Section IV of Appendix A with the exception of "Collect Contaminated Building Samples". This program is not applicable at OU1, as described below.

- **OU1 Reconnaissance** – Conduct OU1 surveys, which may include but not be limited to OU1 surveys, land surveys, topographic mapping, and field screening.

OU1 reconnaissance was conducted as part of the kick-off meeting held on 15 December 2006. Subsequent reconnaissance was conducted on 11 and 12 April 2007. SulTRAC will be providing flyover data to the Respondent, which includes topographic information on a 1-ft contour. Topographic mapping of sampling locations will be conducted as the RI fieldwork is performed. Limited field screening using a photo-ionization detector (PID) is proposed as part of the Carus (OU1) main plant area investigation, described in Section 2.2.2 of the FSP.

- **Geologic Investigations (Soils and Sediments)** – Determine the extent of hazardous substances, pollutants or contaminants in surface soils, subsurface soils, and sediments. Section 2.2 of the FSP addresses the solid matrix characterization program proposed for OU1. This program includes sampling soil, as well as slag. During this characterization program, the extent of hazardous substances, pollutants, or contaminants in soil and slag will be evaluated, and the horizontal, vertical, and elevation coordinates will be established for all sampling points in accordance with USEPA Region 5 electronic data requirements. Sediment samples are proposed for the Little Vermilion River, and one upland sediment sample is proposed in the lone area of upland ephemeral seepage observed. No other sediment samples are proposed for the OU1 area.
- **Air Investigations** – Determine the extent of atmospheric hazardous substances, pollutants or contaminants at and from OU1. As described in Section 2.6 of the FSP, an ambient air sampling program is proposed to address metals, particularly arsenic and lead, as well as asbestos. These two metals were selected because they have been found to be elevated in slag samples collected from the Site and are a potential worker exposure concern. Asbestos was selected due to concerns associated with potential airborne deposition of asbestos from the demolition of historic buildings containing asbestos located on OU1 and OU2. It is thought that asbestos may have been deposited within the slag, and disturbance of this material may cause the asbestos to become airborne.
- **Hydrogeologic Investigations (Groundwater)** – Determine the horizontal and vertical distribution of hazardous substances, pollutants or contaminants in the groundwater and the extent, fate, and transport of any groundwater plumes

containing hazardous substances, pollutants, or contaminants. Section 2.4 describes the groundwater investigation proposed for OU1 to meet the objectives described above. The existing network of monitoring wells will be supplemented by additional wells and groundwater samples collected to evaluate the horizontal and vertical distribution of hazardous substances, pollutants, or contaminants in the groundwater. The proposed well network is designed to provide a representative sampling of geologic media present on-site. Extensive analytical data and geochemical parameters will be collected to evaluate the extent, fate, and transport of any groundwater plumes containing hazardous substances, pollutants, or contaminants. Hydraulic testing will be performed and potentiometric data will be collected to assess groundwater flow regimes at the OU1 site.

- **Hydrologic Investigations (Surface Water and Sediments)** – Determine the nature and extent of contamination of surface water from OU1, including, but not limited to: collection of surface-water samples, measurement of surface-water elevation, and collection of sediment samples. One area within OU1 has been documented as a surface-water accumulation area. One surface-water sample and one sediment sample (co-located) will be collected from this area if surface water is present during the RI. In addition, a surface-water basin analysis will be conducted as described in Section 7.8 of the Work Plan to evaluate potential surface-water flow pathways as a result of stormwater events. Limited surface-water and sediment samples are also proposed if surface-water accumulation is found in the OU1 area during the RI, as described in Section 2.3 of the FSP.
- **River Sampling (Surface Water, Sediment, and Benthic)** – Determine the nature and extent of contamination along the entire M&H Site (both OU1 and OU2), downstream of the Site, and upstream of the Site, including, but not limited to: collection of surface-water samples, measurement of surface-water elevation, collection of sediment samples, and collection of the benthic community within the river. As described in Section 2.3 of the FSP, physical characterization is proposed to map out the slag present in the Little Vermilion River, as well as to document sediment depositional areas. Limited sediment and surface-water sampling is proposed as an initial phase of investigation. Additional analytical sampling will be performed, if warranted, based on the

results of the initial phase of work. A benthic sampling program will be developed as necessary to support the ecological risk assessment, following completion of the habitat characterization described in Section 2.5 of the FSP.

- **Waste Investigation** – Characterize the waste materials at OU1, including collecting waste samples and disposing of derived waste. Slag is by far the most prominent waste material located within the OU1 area. An extensive slag characterization program is described in Section 2.2 of the FSP. Investigation-derived waste (IDW) will be managed as described in Section 5 of the FSP.
- **Conduct Geophysical Investigation** – Delineate waste depths, thicknesses, and volume related to OU1; determine the elevations of the underlying natural soil layer, and the extent of cover over fill areas. Extensive geophysical investigation is not warranted to delineate waste depths, thicknesses, and volume related to OU1, determine the elevations of the underlying natural soil layer, and evaluate the extent of cover over fill areas. Drilling and trenching will be used to collect the required information to meet these objectives.
- **Ecological Investigation** – Assess impacts to aquatic and terrestrial ecosystems from the disposal, release, and migration of hazardous substances, pollutants, or contaminants at OU1 including wetland and habitat delineation, wildlife observations, community characterization, identification of endangered species, and biota sampling and population studies. An ecological investigation and risk assessment will be conducted during the RI, as described in Section 7 of the Work Plan. The habitat characterization, which will include habitat delineation, wildlife observations, and threatened/endangered species identification, is described in Section 2.5 of the FSP. The ecological risk assessment plan described in the Work Plan presents a likely approach for a Baseline Ecological Risk Assessment (BERA), which, if necessary, will include population and community analyses.
- **Contaminated Building Samples** – Collect contaminated building samples as necessary. No building samples are proposed in OU1 because all of the existing buildings present on OU1 are part of an active manufacturing facility and are regulated under Occupational Safety and Health Administration (OSHA) to ensure worker safety and protection. Although asbestos is present in some of the building materials used to construct site buildings, Carus has an active

Asbestos Management Plan to address any asbestos concerns.

- **Investigation-Derived Waste** – Characterize and dispose of IDW in accordance with local, State, and Federal regulations. Section 5 of the FSP discusses the proposed environmental program for management of IDW.
- **Treatability Studies** – If the Respondent or USEPA identify possible remedial actions for OU1 that involve treatment, the Respondent will include treatability studies. Currently, the RI has not progressed to the point where remedial actions have been identified. As the RI progresses, if the need for treatability studies is identified, the Respondent will submit a Treatability Study Work Plan for USEPA review and approval in accordance with the procedures set forth under Task 5 of the Statement of Work (Appendix A to the ASAOC) and the treatability study will be implemented as early as possible during the RI/FS process.

1.3 Site History and Background

1.3.1 Site Location

OU1 is a portion of the broader M&H Zinc Company Superfund Site, located on the east side of LaSalle, Illinois. Figure 1 presents an overview of the Site, which encompasses approximately 183 acres of defined property plus any off-property areas, such as the Little Vermilion River, which may have been affected by the Site's manufacturing history. The Site is divided into two operable units: (i) OU1, comprising the Carus facility in the southern portion of the Site, the slag pile created from M&H operations, and the Little Vermilion River; and (ii) OU2, comprising the former M&H Zinc Company in the northern portion of the Site, as well as any impacts to residential or other areas in the City of LaSalle. The ASAOC requires Carus' participation in a site-wide RI/FS, which, for Carus, specifically entails: (i) performance of OU1-related activities; and (ii) combination of investigative findings from OU1 with those from OU2 provided by USEPA's contractor into site-wide reports, as needed.

1.3.2 Site Operations History

The TLR, prepared by Geosyntec on behalf of Carus, pursuant to the ASAOC, presents a detailed, chronological review of site history for OU1 and OU2, including an aerial photograph review. This section presents a summary of the operational history of OU1 and OU2. For a more detailed discussion, the reviewer is referred to the TLR. This summary begins with a discussion of OU2, as the former M&H Zinc Company Site operations predate and are directly relevant to OU1.

OU2 property, located at 900 Sterling Street north of the Carus manufacturing facility, began operations primarily as a zinc processing facility in the mid 1800's under the name of Matthiessen and Hegeler. Zinc ore was imported to the M&H Zinc Company where it was refined, recovered, and rolled for industrial use. In the late 1800's, Matthiessen and Hegeler exploited a new technology whereby the sulfur dioxide emissions from the zinc refining process could be converted to sulfuric acid; this became another plant process. By-products, including sinter, slag, and other off-specification materials, were placed south and east of the M&H Zinc Company operational area. Portions of the slag and sinter were placed on property now owned by Carus. Based on comparisons of aerial photographs, by 1939, most of the slag had been placed in its current location. In the late 1970's, M&H Zinc Company reportedly filed for bankruptcy, and operation of the rolling mill was taken over by Zinco. In 1991, Zinco merged with LaSalle Rolling Mills, which was the surviving corporation. LaSalle Rolling Mills continued operations until the late 1990's and performed smelting, rolling, casting, stamping, and plating of zinc and aluminum sheet and wire products. Beyond some warehousing, there are no known current operations on the former M&H Zinc Company property comprising OU2.

Based on the plat survey, in 1876, a large portion of the property now owned by Carus (i.e., OU1) was likely used for agricultural purposes. The manufacturing and business operations of Carus and M&H Zinc Company have always been separate. Carus began operations in 1915 manufacturing potassium permanganate products used for water purification and wastewater treatment. Today, approximately 15,000 tons of potassium permanganate are produced annually at the Carus facility. Additionally, Carus produces sodium permanganate and a specialty line of products. Sodium permanganate is used by the electronics industry for descumming and descaling. Other products are used for denim highlighting, chemical synthesis and purification, wire descaling, and acid mine

leachate treatment. Air filter media are produced for air purification use in residential, commercial, and industrial buildings.

1.3.3 Site Description

OU1 is comprised of three primary areas: (i) Carus' manufacturing facility (referred to herein as the main plant area); (ii) a slag pile related to the former M&H smelter operations; and (iii) the Little Vermilion River. The Carus manufacturing facility is located at 1500 Eighth Street, in the northwest quarter of Section 14 and in the northeast quarter of Section 15 in Township 33 North, Range 1 East of the Third Principal Meridian in LaSalle County, Illinois. The slag pile is located in the northwest quarter of Section 14 in the township referenced above and is bordered to the east by the Little Vermilion River. The river generally runs from north to south toward its confluence with the Illinois River approximately one mile south of the Site; it also serves as the eastern boundary of OU1 and OU2. Note that the northern boundary of the slag pile serves as part of the boundary between OU1 and OU2; this boundary is dashed on associated figures because the boundary is estimated at present. Likewise, the spatial extent of site-related impacts in the Little Vermilion River will be better understood during and after RI characterization; hence, dashed boundary lines immediately to the north and south of the Site indicate possible study boundaries. The main plant area of OU1 contains numerous buildings associated with the manufacture of potassium permanganate and other specialty chemicals. Property to the east of the main plant area includes, from west to east: (i) the eastern embankment of the main plant area; (ii) a segment of the former Illinois Central Railroad (ICRR) embankment; and (iii) the slag pile associated with the M&H Zinc Company Site. A holding pond and an emergency bypass pond associated with Carus' operations and its National Pollutant Discharge Elimination System (NPDES) permit are located on or near the slag pile. The holding pond receives non-contact process water and stormwater through a sewer system, as well as overland flow. The holding pond operates under NPDES permit number IL0002623 and discharges to the Little Vermilion River. OU1 is bounded by OU2 of the M&H Site to the north; a limestone quarry, a cemetery, and farmland to the east; and private residences to the south and west.

1.4 Understanding of Contaminant Characterization

This section briefly summarizes the TLR's review of previous OUI investigations and includes a summary defining the current understanding of contaminants at the Site.

1.4.1 Chronology and Rationale of Historical Investigations

Soil, slag, groundwater, surface-water, and sediment samples have been collected at OUI as part of prior investigations conducted by Geosyntec and Illinois Environmental Protection Agency (IEPA). The investigations and their purpose are described as follows:

- **Preliminary Assessment Report (Carus):** The CERCLA Preliminary Assessment Report was prepared by the IEPA following placement of the Carus main plant area in the Comprehensive Environmental Response, Compensation and Liability Information System (CERCLIS) in May 1991. The purpose of the Preliminary Assessment Report was to conduct an initial evaluation of the Site and recommend to the USEPA a priority for conducting additional investigations as part of the CERCLA process. No environmental samples were collected during this effort.
- **Screening Site Inspection (Carus):** A CERCLA Screening Site Inspection (SSI) was conducted in 1991 by the IEPA for the Carus main plant area, which is now included in OUI. The purpose of the SSI was to: (i) collect additional data in order to perform a preliminary Hazard Ranking System (HRS) site score; (ii) establish priorities among sites most likely to qualify for the National Priorities List (NPL); and (iii) identify the most critical data requirements for any further investigation, if necessary. The scope of work conducted as part of the SSI included the collection of four surface soil samples, one background surface soil sample, eight sediment samples, three groundwater samples from on-site monitoring wells, and one background groundwater sample.
- **Preliminary Site Investigation (Carus):** The Preliminary Site Investigation (PSI) was conducted by Geosyntec at the Carus main plant area in October 1992. The objectives of the PSI were to: (i) assess chemical constituents contained within the soil, sludges, and groundwater; (ii) examine visually the subsurface materials; (iii) collect soil samples for laboratory analysis; and (iv)

install additional groundwater monitoring wells. The scope of work conducted as part of the PSI included the following: (i) advancement of 16 soil borings for visual classification and analytical sampling; (ii) installation of two groundwater monitoring wells; (iii) collection and laboratory analysis of soil and sediment samples from the Little Vermilion River and the holding pond; (iv) collection of five unfiltered groundwater samples from the two newly installed monitoring wells and three existing wells (those sampled during the IEPA SSI in November 1991); (v) measurement of water levels in monitoring wells to evaluate groundwater flow; and (vi) performance of a single well aquifer test (slug test) in a monitoring well located within the slag-deposit area east of the railroad embankment.

- **1993 Investigation (Carus):** The investigation in November of 1993 was conducted by Geosyntec at the Carus main plant area to: (i) evaluate the constituents at three locations of the Site, including concentration and extent; (ii) assess the data to more accurately depict the hydrogeology; (iii) investigate and identify potential migration pathways; (iv) obtain the data necessary to develop an action plan; and (v) satisfy requirements of the Illinois Pre-Notice Site Cleanup Program. The scope of work conducted as part of the November 1993 investigation included the following: (i) advancement of 18 soil borings; (ii) completion of three of the soil borings as groundwater monitoring wells; (iii) performance of a water supply well exposure survey; (iv) evaluation of existing groundwater monitoring wells; (v) slug testing; (vi) water level measurements; (vii) soil sampling and analysis; (viii) surface-water sampling and analysis; and (ix) groundwater sampling and analysis. The water supply well exposure survey included the following activities: (i) conducting interviews with various individuals who were familiar with water use in the area (including the Mayor of LaSalle, the City Engineer, and the Director of Public Works); (ii) reviewing utility system maps; and (iii) evaluating well construction reports.
- **1994 Investigation (Carus):** Geosyntec continued its investigation in 1994. The purposes of the 1994 investigation included: (i) characterization of the nature and extent of chemical constituents in the portion of the slag pile in OU1 on Carus property; (ii) evaluation of the impacts on groundwater and the Little Vermilion River; (iii) identification of the potential sources of any such impacts; and (iv) satisfaction of the requirements of the Pre-Notice Site Cleanup

Program. The scope of work included the following elements: (i) a site inspection; (ii) evaluation of the holding pond; (iii) meteorological assessments; (iv) surface-water sampling in the Little Vermilion River and analysis; (v) sediment sampling and analysis in the Little Vermilion River; (vi) advancement of 18 soil borings, and soil sampling and analysis, principally in the slag pile; (vii) installation of 10 piezometers; (viii) water-level measurements; (ix) slug and pump tests; and (x) groundwater sampling and analysis.

- **Preliminary Assessment Report (M&H Zinc Company Site):** The CERCLA Preliminary Assessment Report was prepared by the IEPA in 1994 following the CERCLA SSI of the Carus Site conducted in November 1991, at which IEPA noted large piles of slag material. The report provided an operational and regulatory history of the M&H Zinc Company and summarized the findings of the site visit. Groundwater, surface-water, air, and soil migration pathways were discussed. No environmental samples were collected during this effort.
- **Integrated Site Assessment (M&H Zinc Company):** The CERCLA Integrated Site Assessment was conducted in December 1993 by IEPA to “help characterize the nature of sources, and to determine if these sources had impacted nearby human populations or the environment”. Investigative activities of the IEPA sampling team included: (i) collection of four sediment samples from the Little Vermilion River; and (ii) collection of eight soil samples. Of the eight soil samples, three were collected from the slag pile located within OU1. In addition, thirteen soil samples were collected off-site at residences near the Site.

1.4.2 Summary of Investigative Findings

The following conclusions are based on all of the data collected and observations noted during the investigations conducted to date on OU1:

- Slag material associated with past smelting operations (M&H Zinc Company) was placed within the Little Vermilion River Valley and encroaches upon and has changed the course of the Little Vermilion River. The M&H Zinc Company generated and placed these materials prior to acquisition of the property by Carus.

- Slag material (and groundwater within the slag) is likely to be at least partially in direct contact with the surface water in the Little Vermilion River. The groundwater within the slag discharges to the Little Vermilion River.
- Groundwater within the slag and the alluvium of the Little Vermilion River is isolated from the deeper aquifer by more than 1,000 ft of alternating layers of low permeability shales and limestones. This groundwater is distinct from the shallow perched groundwater in the Carus manufacturing area.
- The sinter and slag areas are the primary sources of chemical constituents in the environment at OU1. The data indicate that metals are more broadly distributed and at higher concentrations relative to media screening values than are organic chemicals whose presence is sporadic.
- Impacts to soils located within OU1 may include arsenic, chromium, iron, lead, and manganese (based on totals data), as well as zinc and cadmium (based on Toxicity Characteristic Leaching Procedure (TCLP) data).
- The sinter and slag source areas appear to have had only a very minor impact on groundwater at the Site due to the low leaching potential and immobility of the constituents bound in the sinter/slag matrix. The sand and gravel aquifer below the Site has only been minimally affected.
- Relatively minor impacts to groundwater quality with respect to human health screening criteria have been detected in monitoring wells screened within the slag pile. These impacts primarily include aluminum, arsenic, cadmium, chromium, iron, lead, manganese, nickel, and zinc. These elevated concentrations may be associated with turbidity of groundwater samples, and may not reflect the mobility of the constituents in groundwater.
- An isolated area of elevated levels of benzene, toluene, ethylbenzene, and xylene (BTEX) in groundwater were identified (November 1993) in the extreme northeast corner of the Carus main plant area. These impacts are believed to be associated with miscellaneous spills from a former above-ground storage tank.
- Elevated levels of metals are present within the slag. From the standpoint of the potential for exposure of chemicals to humans through direct contact, the slag

pile is located in a low-traffic area and site access is controlled by fencing and periodic patrols by off-duty police officers.

- Elevated levels of organics and metals were measured within sediment samples collected from the holding pond. Results for these samples were evaluated with respect to ecological screening criteria. Impacts to sediment include elevated levels of arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, acetone, anthracene, arochlor 1254, benzo(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, fluoranthene, phenanthrene, and pyrene. The polycyclic aromatic hydrocarbons (PAHs) may be related to the mining and use of coal historically in industrial operations at and surrounding the Site.
- Elevated levels of metals were measured within some of the surface-water and sediment samples collected from the Little Vermilion River. Results for samples collected in the river were evaluated with respect to ecological screening criteria. Impacts to sediment include elevated levels of arsenic, cadmium, copper, cyanide, lead, mercury, nickel, and zinc. Impacts to surface water include elevated levels of cyanide, iron, lead, mercury, and zinc. The types of metals and the concentrations observed may indicate potential impacts to the Little Vermilion River from the presence of slag.

1.5 Potential Sources of Contamination

The primary potential sources of contamination at OU1 are:

- slag pile associated with OU2 operations;
- slag transported within the Little Vermilion River from the slag pile;
- historical processes and waste management practices associated with OU1 operations; and
- historical processes and waste management practices associated with OU2 operations (due to groundwater and surface-water flow pathways, as well as airborne deposition).

1.6 Data Gaps

1.6.1 Introduction

The TLR concludes with an identification of data gaps. Section 6 of the Work Plan discusses the data needs in greater detail based upon the TLR, as well as the additional analysis presented in Section 4 of the Work Plan. This section summarizes the additional data needs identified for OU1. Data collected during the RI/FS will serve four major needs: (i) physical characterization of site media; (ii) characterization of the nature and extent of contamination; (iii) refinement of understanding of chemical fate and transport and risk mechanisms; and (iv) data to support remedy evaluation. Data needs for these four major areas will be discussed individually below.

1.6.2 Physical Characterization Needs

Physical characterization is necessary to understand site media or submedia that are likely to serve either as sources or pathways in complete source-pathway-receptor scenarios. The two most important site submedia in this regard are the slag and its underlying alluvium. Obtaining a better understanding of the lateral and vertical extent of the slag pile will assist in the modeling of leachability and transport scenarios, as well as the development of conceptual exposure areas for human health risk assessment (HHRA). Quantifying the thickness of the alluvium underneath the slag will assist with the quantification of potential mass loading in a downgradient transport scenario.

Physical characterization of the Little Vermilion River is necessary to identify and quantify slag that has been transported down the river, as well as deposited within the floodplain. This physical characterization is important as the slag is a potential source of contamination to the sediments and surface waters within the Little Vermilion River. Obtaining a better understanding of the geomorphologic setting and processes (e.g., resuspension, transport, deposition, and weathering) will assist in understanding the stability of both the slag and the sediment.

1.6.3 Nature and Extent of Contamination

While the historical dataset provides a considerable level of understanding of constituent impacts to site media, several gaps in the extent of characterization have been identified. These data needs include the following:

- The metals analyte list employed throughout the past characterization programs was not always as comprehensive as now required. Specifically, 1994 investigation analyses tended to limit the metals analyses to the highest priority metals. As a result, much of the solid-matrix and groundwater datasets for the slag and underlying alluvium include a limited analytical list. With the added consideration of ecological screening values as part of the CERCLA process, a broader consideration of metals is necessary. Hence, it is recommended that additional data be collected that employs a full target analyte list (TAL).
- A number of detections of ancillary constituents (e.g., PAHs, polychlorinated biphenyls (PCBs), pesticides, etc.) exceeded applicable screening values. It is recommended that further site characterization include these ancillary analytical groups in a percentage of samples. As indicated earlier, widespread areas of contamination are not anticipated; however, the historic data suggest that an expanded survey is appropriate. The one area where a more focused investigation of non-metallic chemicals of potential concern (COPCs) is warranted concerns pesticides in the northern reaches of the river.
- Additional groundwater monitoring locations are recommended. The conceptual site model (CSM) of groundwater fate and transport, as presented in Section 4, discusses several potential pathways of groundwater flow; of these, the most significant are: (i) southward flow in the alluvium underneath the slag (of human health concern); and (ii) eastward discharge of groundwater from the slag into the river (primarily of ecological concern). Hence, a refined understanding of groundwater conditions in the slag and in the underlying Holocene alluvium is warranted. At the same time, improving the understanding of groundwater conditions in other site media, including Pennsylvanian bedrock, Pleistocene till, and fill, particularly in background locations, will improve the understanding of background conditions, as well as the overall hydraulic flow system.
- Updated, summary groundwater characterization and potentiometric mapping is recommended to obtain a “current baseline” of data. Given the sensitivity of metals concentrations to well condition and sampling method, the condition of groundwater monitoring wells should be evaluated, with redevelopment or replacement a consideration in each case. In particular, it is recommended that

the area of historical BTEX impacts (monitoring well G-04) undergo confirmation.

- Past characterization of shallow (0 to 5 ft BLS) soils was focused on certain areas of potential concern within the Carus main plant area. Additional sampling locations are warranted to collect subsurface data and to achieve a more even spatial distribution.
- An updated and more densely spaced series of sediment and surface-water samples, using broad analytical suites, is warranted for the Little Vermilion River to understand potential impacts from the M&H Zinc Company Site. Evaluation of overland flow is also warranted during the RI. As part of the overland flow evaluation, surface-water and sediment samples may also be collected, using a broad analytical suite for sample analysis.

1.6.4 Fate, Transport, and Risk Mechanisms

Developing a detailed understanding of the geochemistry of site media is a critical component of a thorough RI/FS for a metals-dominated project such as the M&H Site. Site data collected to date indicate that the 15 priority metals can exist in a significant variety of species with widely varying mobility, bioavailability, and stability. While conventional, total metals concentrations are often adequate for risk assessment, obtaining a more detailed understanding of metals speciation through specialty analyses will provide one or more of the following benefits:

- Certain specialty analyses, such as Acid Volatile Sulfide/Simultaneously Extracted Metals (AVS/SEM) analyses, are necessary to accurately quantify the true ecological risk because they indicate the fraction of metals concentrations that are not bioavailable even if present in site media. As such, they serve as an extension of the characterization of the nature and extent of contamination.
- Other analyses clarify the mechanisms by which metals sorb to site media, which will considerably improve the conceptual model of attenuation, if it is occurring. By understanding the attenuation mechanisms, it may be possible to more precisely and accurately predict future concentrations, which will assist in risk-based decision making and identification of remedial options.

- Various potential remedies may affect site geochemical conditions in a variety of ways. Because the mobility of the metals on the Site is controlled by the geochemical conditions, gaining a better understanding of the speciation of metals at the Site will allow for a better understanding of the impacts that various remedies may have on metals mobility.

Certain OUI reconnaissance activities are necessary for the development of the ecological risk assessment. The two most important activities will include: (i) a reconnaissance of sediment deposition patterns in the river to refine sediment sampling locations; and (ii) a habitat survey, addressing terrestrial, riparian, and aquatic systems to refine the selection of receptors for the risk assessment.

1.6.5 Remedy Evaluation Data

Much of the specialty analytical work to explore metals geochemistry will support an evaluation of remedial alternatives. Additional activities geared specifically for remedy evaluation, such as geotechnical borings to evaluate slag pile stability, are likely to be performed during the FS.

1.7 Sampling Objectives

The overall goal of the RI/FS process is to collect sufficient data to characterize the extent of contamination at the Site, support the human health and ecological risk assessments, and provide an FS for a range of potential remedial options leading to USEPA's selection of a proposed remedial action for the Site.

Historic site investigation data and additional RI/FS site investigation data will be used to evaluate potential exposure pathways and to evaluate potential remedial alternatives protective of human health and the environment. Data collected during the RI, in addition to historic data, will be utilized to meet the specific objectives described in Section 5 of the RI/FS Work Plan.

The objectives of this FSP are to:

- present the rationale for the number and types of environmental samples to be collected during the field investigation;

- present the rationale for the selection of sampling locations;
- describe the procedures to be used for collection, preservation, packaging, and transport of environmental samples;
- present documentation requirements for sample activities and sample custody;
- describe the procedures for characterization and decontamination of environmental sampling equipment; and
- describe the procedure for the disposal of IDW.

These objectives are fully defined in each of the sampling activities for Section 2 of the FSP. Rationale for the proposed sampling plan is also included within the text of Section 2. The FSP has been prepared primarily for use by field personnel to ensure sample collection and analytical activities are conducted in accordance with technically accepted protocols and that the data meet site-specific Data Quality Objectives (DQOs) established in the QAPP. Accordingly, the intent of this FSP is to provide the procedures required to implement the program outlined in the RI/FS Work Plan for the Site.

2. FIELD ACTIVITIES

2.1 Mobilization and Site Access

2.1.1 Pre-Investigation Activities

Much of the field investigation activities will take place continuously over the course of several months. To reduce potential problems in the field, the following tasks, at a minimum, should be completed prior to conducting field activities:

- coordinate the project schedule and provide notification to USEPA, USEPA contractors (e.g., SulTRAC, a joint venture of Sullivan International Group and Tetra Tech EMI), and IEPA;
- contact the laboratory to review analytical requirements, provide sample containers, and discuss delivery and pickup of coolers and packages;
- contact subcontractors to review the scope of work, schedule field activities, and discuss special equipment needs;
- contact public and site utility location staff if drilling or excavating activities are scheduled;
- order field supplies and secure specialized equipment needed to complete field activities;
- provide copies of project documents to field personnel; and
- review the scope of work with the Project Manager to identify any potential problems.

2.1.2 Site Access Control

Site access control is of the highest importance to protect the public from exposure to chemicals at the Site during RI/FS field investigation activities. All visitors to the Carus facility must check in daily at the front office and be badged. The main plant area is fenced and access is controlled by gates. During the work day, access is limited to one open gate (the main entryway); however, this gate is closed at night. All visitors to

OU1 must check in with the Potentially Responsible Party (PRP) Field Manager before being allowed to enter work areas. Visitor information (e.g., affiliation, reason for access, etc.) will be documented in the field log book. Unauthorized visitors will not be allowed to enter work areas. Visitors will only be allowed to enter the Exclusion Zone (EZ) with permission from the Site Health and Safety Officer (SHSO). Where applicable, proof of Hazardous Waste Operations and Emergency Response (HAZWOPER) training and evidence of participation in a medical surveillance program will be required before being allowed to enter the work area. Specifically, for on-site work and off-site work areas where reference samples for sediments and surface water will be collected, visitors will be required to present to the SHSO: (i) a copy of their completion certificates for 40-hour HAZWOPER training and 8-hour refresher training, if applicable; and (ii) evidence of participation in a medical surveillance program for inclusion in the HASP. All personnel entering the Site will review and sign the HASP.

2.1.3 Field Standard Operating Procedures

SOPs referenced in this document are listed below. The individual SOPs are included in Appendix D of the RI/FS Planning Documents.

<u>SOP No.</u>	<u>Description</u>
100	Water Level Measurement Procedures
110	Groundwater Sampling Using the Low-Flow Protocol
120	Construction of Monitoring Wells
130	Monitoring Well Development
140	Well Abandonment
150	Slug Test
160	General Pumping Test Procedures
200	Surface Soil Sampling
210	Soil Description Visual-Manual Procedure of the United Soil Classification System
220	Test Pit Logging
230	Soil and Rock Boring
240	Direct Push Soil Sampling
300	Surface Water and Sediment Sampling

<u>SOP No.</u>	<u>Description</u>
410	Packaging and Shipping of Environmental Samples
500	Ambient Air Sampling (from USEPA)
600	Habitat Characterization

2.2 Solid Matrix Investigation

2.2.1 Introduction and Sampling Rationale

This section of the scope of work is referred to as “solid matrix” sampling instead of “soil” sampling, because it includes both waste material (e.g., slag and sinter) and true soil. Figure 2 presents an overview of the solid matrix sampling program. The program addresses two major sampling areas: (i) the slag pile; and (ii) the Carus main plant area. Table 1 provides the proposed analytical parameters. All solid matrix samples will be analyzed for TAL metals as they are the most prevalent chemicals present in soils and slag based on previous investigations conducted in the OU1 area. A subset of samples will be analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, PCBs, and cyanide, as these chemicals have been measured in site media to a more limited extent than the metals. The relative percent purposed is consistent with the relative observations measured in site media during earlier investigations at OU1. As demonstrated in Table 1, the samples designated for VOCs, SVOCs, pesticide, PCBs, and cyanide were selected on a rotational and sequential basis to ensure a randomly spatial sampling design (no bias as to sampling depth or location). Geochemical parameters are also being collected to evaluate fate and transport mechanisms and bioavailability in the soil and slag. All of this data will be used for media characterization purposes, as well as for input into the human health and ecological risk assessments.

Ten borings (SB-301 through SB-310) will be advanced within the slag located in OU1. A total of 33 samples will be collected from the borings at various depths, as described in Section 2.2.2. This number of samples is sufficient to characterize the slag, especially given the amount and quality of the existing data within the slag, the stability of the chemicals found within the slag (primarily metals), and homogeneity of the slag samples. The boring locations have been selected to fill spatial gaps remaining after a consideration of historical data.

Nine borings (SB-311 through SB-319) will be advanced in the main plant area. A total of 21 samples will be collected from the borings at various depths, as described in Section 2.2.2. This number of samples is sufficient given the amount and quality of existing data generated from the OU1 main plant area and limited exposure to surface soils in the main plant area (the majority of the Site is developed with buildings or is paved with concrete or asphalt). The programs for the two areas can be summarized as follows:

Slag Pile Area Program: The slag pile area program consists of ten borings with sampling intervals on multiple horizons. In general terms, each boring will include samples collected from: (i) 0 to 1 ft below land surface (BLS) to characterize direct contact risks; (ii) 5 ft above the water table; and (iii) 5 ft below the water table. The indicated sampling horizons were selected because they represent three distinct geochemical environments: (i) surficial, with maximal exposure to air; (ii) deep vadose zone, with very limited exposure to moisture and air; and (iii) saturated zone, with no exposure to air and maximum exposure to water. Additional sampling horizons were deemed unnecessary in light of the vertical homogeneity of slag concentrations observed during sampling performed in conjunction with the 1994 investigation. The analytical program will consist of the following:

- TAL metals for all samples;
- VOC, SVOC, and cyanide analyses for approximately 25% of samples;
- pesticides and PCBs for approximately 25% of samples;
- TAL Synthetic Precipitation Leaching Procedure (SPLP) and soil pH in approximately 33% of samples;
- Sequential Extraction Procedure (SEP) analyses in five samples; and
- X-Ray Diffraction (XRD) analyses in three samples.

The slag characterization program will also address the physical characterization necessary to delineate waste (slag) depths, thicknesses, and volume related to OU1, as well as the elevations of the underlying natural soil layer and the extent of cover (if present) over the slag. The proposed physical characterization program will include

two components: (i) advancing three of the slag pile borings (SB-301, SB-305, and SB-310) through the slag and underlying alluvium to the top of bedrock surface in accordance with SOP No. 230, and (ii) test trenching with a backhoe to delineate the southern, western, and northern edges of the slag pile on 150 ft centers (no boundary points are anticipated for the eastern boundary as that is where the slag meets the Little Vermilion River). The slag material is visually distinct from the natural soils, providing a mechanism for evaluating the extent of slag when drilling to the natural soil layer underlying the slag or trenching perpendicular along the slag/natural soil interface.

Test trenches will be dug on 150-ft centers along the boundary of the slag. Test trenches will be excavated perpendicular to the slag pile boundary. The length of each test trench may vary as needed to document the interface between the natural soils and the slag. The depth of each test trench will extend to the reach of the backhoe, or to competent rock, whichever is encountered first. Test trenches will be logged in accordance with SOP No. 220.

The objective of the slag characterization program is to obtain a better understanding of the lateral extent of the slag and the vertical thicknesses of the slag and alluvium. These objectives support: (i) the development of conceptual exposure areas for human health/ecological risk assessment; and (ii) quantification of potential mass loading in groundwater transport scenarios. While a detailed discussion of DQOs has not been presented for this specific scope, it is reasonable to assume that the conventional approach proposed will be adequate. Geophysics is valuable for providing information at depth, whereas a detailed surficial delineation is necessary for risk assessment. Use of a backhoe to perform test trenching will be a cost-effective and accurate means of delineating the surficial expression of the slag. For transport estimates, an order-of-magnitude estimate is sufficient at present; hence, obtaining vertical slag/alluvium geometry in two locations should be adequate. If a more detailed model is desired in the future, a more detailed program can be designed. As such, no additional geophysical investigation is proposed (e.g., seismic refraction, ground-penetrating radar, cone penetrometer survey, etc.) at present as these methods are not necessary to delineate depths, thicknesses, and volume related to slag within OUI.

Main Plant Area Program: The main plant area program consists of nine locations with two samples each at 0 to 1 ft and 2 to 4 ft BLS to support risk assessment. While only a long term commercial/industrial scenario will be considered for the main plant

risk assessment, characterizing the surficial and subsurface zones will allow a differentiation of risks between general site use (for which shallow data are relevant) and construction worker activities (which involve deep soils). This may be of value in remedy evaluation/selection, because if the deeper horizon exhibits higher risks than those of the shallow horizon, it may be possible to impose land disturbance restrictions as a remedy component. The analytical program will include the following:

- TAL metals for all samples;
- VOC, SVOC, and cyanide analyses for approximately 25% of samples;
- pesticides and PCBs for approximately 25% of samples;
- SEP analyses in four samples; and
- XRD analyses in three samples.

Table 1 provides a detailed record of the required analyses for each sample. The SPLP and pH analyses are employed in the slag pile due to the anticipated potential for leachability; they are omitted from the main plant area program because of lower concentrations. However, the XRD and SEP analyses are tested in both areas, because both areas will require consideration of bioavailability based on concentrations elevated above screening values.

2.2.2 Sampling Details

The field investigation within the main plant area will include the collection of soil samples from nine direct-push technology (DPT) (e.g., Geoprobe®) soil borings advanced in the vicinity of the production buildings and the emergency holding pond. Soil sample locations are shown on Figure 2.

DPT borings at the main plant will be advanced to a maximum depth of 4 ft. Samples from each 2-ft interval will be field-screened for organic vapors with a hand-held PID. Field screening results will be used to select samples for laboratory analysis. Samples will be selected for laboratory analysis as follows:

- a sample collected from the 0 to 1 ft BLS or, if concrete/pavement is present, the first 0 to 1 ft below the concrete/pavement; and
- a sample collected from 2 to 4 ft BLS, unless PID readings above background are observed, in which case the second sample will be targeted to a 2-ft interval centered on the horizon with highest PID readings.

At the slag pile area, ten hollow-stem auger (HSA) borings will be advanced. Samples collected from these borings will be used to characterize COPCs and geochemical conditions of the slag pile in these areas. A minimum of three samples per boring will be collected for laboratory analysis. Solid samples will be collected at intervals of 0 to 1 ft BLS, 5 ft above the water table, and 5 ft below the water table for samples in the slag pile area. Exceptions to this general rule are:

- if the slag terminates before 5 ft below the water table, the third sample will be collected in the saturated zone 1 ft above the bottom of the slag; and
- if the bottom of slag is above the water table, then the second sample will be collected 1 ft above the bottom of slag or 5 ft above the water table (whichever is higher), and the third sample will be collected in alluvium at least 1 ft below the bottom of slag and up to 5 ft above the water table.

Sampling depths will be selected based on core recoveries and a pre-drilling estimate of the depth to water in each boring. Depths to water in each boring will be estimated before drilling based on water level data from nearby monitoring wells and a pre-drilling survey. A review of drilling data from the 1994 Investigation indicates that the water table in the slag pile has an elevation that ranges from 455 to 470 ft above mean sea level (MSL). In addition, the ground surface elevation on the slag pile varies over tens of ft MSL. Hence, before drilling, it will be necessary to survey drilling locations for ground surface elevation and draw a potentiometric surface in the slag pile from available wells. These two data sets can be used to estimate sampling depths for the deep samples. The drilling supervisor will also carefully monitor slag cores to report whether samples are unsaturated or saturated.

In addition, two borings, SB-303 and SB-309, will be advanced to the first five feet of the Holocene Alluvium and sampled at this depth. Proposed slag pile solid sample

locations are also shown on Figure 2 and listed in Table 1. The locations of the borings may be modified in the field dependent on physical impediments and locations of underground utilities.

2.2.3 Solid Sample Collection Procedures

2.2.3.1 Sampling Equipment

Subsurface solid samples will be collected from borings advanced using DPT and traditional augering techniques (e.g., Geoprobe® and HSA). Required sampling equipment includes decontaminated stainless steel bowls and spoons, a scale for weighing samples for VOC analysis, and laboratory-supplied containers. A comprehensive equipment list is documented in SOP Nos. 200 and 240. Downhole drilling tools and sampling equipment will be decontaminated between boring locations. Decontamination procedures are described in Section 4.

2.2.3.2 Logging and Sample Collection

During drilling, cores will be continuously recovered and visually classified in accordance with the Unified Soil Classification System (USCS) per SOP No. 210 and recorded on a field soil boring log. Details regarding solid sample collection will also be recorded in the sample sheets. These details will include sample location, date, and time. Section 3.1 describes in detail the documentation requirements for sampling activities. Procedures for solid sample collection are described in SOP Nos. 200, 230, and 240. Selected samples will be placed in laboratory-provided containers, held on ice, and shipped to the laboratory along with a completed Chain-of-Custody Record. Solid sampling analytical requirements are summarized in Table 1.

2.2.3.3 Sample Containerization

Solid samples will be placed in appropriate laboratory-supplied containers and preserved in accordance with the analytical requirements listed in Table 2.

2.2.4 Sample Handling and Analysis

Proper field sampling documentation and field analytical and laboratory documentation help to ensure sample authenticity and data integrity. Section 3.2 of this FSP describes

the methods for assigning unique sample names. The unique sample name will be used on the sample containers, sample tags, and Chain-of-Custody Record. All solid samples will be placed in laboratory-provided containers, held on ice, and shipped to the laboratory along with a completed Chain-of-Custody Record. Procedures for sample shipping are described in SOP No. 410.

Solid samples will be analyzed using several analytical methods addressing both target parameters and geochemistry. Target parameter methods will include TAL metals (USEPA Methods 6010B/6020/7471A), VOCs (USEPA Method 8260B), SVOCs (USEPA Method 8270C), pesticides (USEPA Method 8081A), PCBs (USEPA Method 8082), and cyanide (USEPA Method 9012A). Specialty analyses to examine geochemistry will include TAL metals SPLP (USEPA Method 1312), soil pH (USEPA Method 9045D), SEP (Laboratory-Specific SOP), and XRD (MSD 0700).

The analyses required for solid samples are summarized in Table 1. With the exception of SEP and XRD analyses, laboratory services will be provided by Columbia Analytical Services (CAS) of Rochester, New York. SEP analyses will be provided by STL Knoxville. XRD analyses will be provided by Materials Analysis Group, Inc. (MAGI). The QAPP provides SOPs for laboratory analyses.

2.3 Surface-Water and Sediment Characterization Program

2.3.1 Introduction and Sampling Rationale

The surface-water and sediment characterization program addresses two areas of the Site: (i) the Little Vermilion River; and (ii) the upland area of OU1. The Little Vermilion River characterization program will be conducted in a phased approach. The first phase includes physical characterization of slag and sediments based on visual observations upstream of the Site extending to the quarry bridge, along the boundary of OU1 and OU2, and downstream of the Site, extending to the confluence of the Illinois River. During the first phase, limited sediment and surface-water sampling will be conducted focusing on sample collection along the M&H Zinc Company Site, as these samples are anticipated to be most heavily impacted by the Site as compared to samples further downstream. As part of this initial sampling effort, a sediment sample will be collected from the sediment depositional area just upstream of the dam located on the Little Vermilion River adjacent to OU2. Based on the results of the first phase of characterization, additional characterization will be proposed, if warranted. Sufficient

data will be collected to characterize the nature and extent of contamination within the Little Vermilion River due to the M&H Zinc Company Site. Benthic samples will not be collected during the initial phase of the investigation; however, as part of the iterative risk assessment process, following completion of the habitat characterization, the benthic sampling program will be developed, as necessary. The surface-water and sediment data will be used as input for the Screening Level Ecological Risk Assessment (SLERA) and the HHRA.

The surface-water and sediment characterization program for the upland area of OU1 will be limited in nature, as the topography of the OU1 area typically does not support development of intermittent streams, ephemeral streams, and overland flow episodes. One noted exception was observed to the west of the abandoned ICRR grade (now a dirt road) just north of the gate located north of the emergency bypass pond. At this location, on 1 May 2007, a seep was observed emanating from the sinter pile (also referred to the ash disposal area on historic M&H Zinc Company maps). The water seeping out of the sinter was observed to accumulate along both sides of the dirt road with no apparent surface-water flow pathway. As such, the surface water is assumed to seep into the ground over time. If this surface water is still present during the RI, a surface-water sample, along with a co-located sediment sample, will be collected. Carus will also observe the OU1 site immediately following a significant rain event to look for additional areas where surface water flow is present. If noted, up to three co-located surface-water and sediment samples will be collected. Areas to be considered will be based on the surface-water basin analysis discussed in Section 7.8 of the Work Plan.

Consistent with other site media, all surface-water and sediment samples collected from both areas (Little Vermilion River and upland area) will be analyzed for TAL metals (the primary concern at OU1 based on site data). A subset of samples will be analyzed for VOCs, SVOCs, pesticides, PCBs, and cyanide, as these chemicals have been observed at the Site, but to a lesser extent than metals. Sediment samples collected from the river will also be analyzed for AVS/SEM for copper, cadmium, nickel, zinc, and lead to evaluate bioavailability.

2.3.2 River Characterization Program

2.3.2.1 Physical Characterization

The objective of the physical characterization program is to collect information that will allow mapping of the Little Vermilion River from the Quarry bridge to the Illinois River with respect to sediment and slag depositional areas. The Little Vermilion River will be traversed by foot or non-motorized vessel (e.g., kayak, canoe, or raft) from the Quarry bridge to the Illinois River (approximately 13,000 ft in length). Visual observations will be noted along the length of inquiry to map both sediment and slag depositional areas. Three levels of slag physical characterization will be conducted: (i) the location of slag boulders (greater than 1 ft in diameter) will be surveyed using hand-held global positioning system (GPS) equipment; (ii) depositional areas where slag gravel and cobbles are present in sizes ranging from about 1/2 inch to 12 inches in diameter will be mapped (these areas will be investigated using shovels and/or grab sampling equipment designed for this type of sampling); and (iii) approximately 20 grab samples will be collected along the river (based on sediment depositional areas) to quantify the slag mass fraction using sieves and scales. Twelve of these locations will be co-located with sediment samples discussed in Section 2.3.2.2 of the FSP.

2.3.2.2 Sample Location and Frequency of River Samples

Surface-water and sediment sampling will be conducted in a phased approach. The first phase of sampling for chemical analyses includes a total of 14 sediment samples and eight surface-water samples, as described below. The initial phase of sampling is focused along the M&H Zinc Company Site as these samples are anticipated to have the potential for the most impact compared to downstream samples. Sediment samples will be collected from the littoral zone, adjacent to the shore, in sediment depositional areas. Surface-water samples will be collected from the approximate midpoint of the water column. Based on the physical characterization (location of slag and sediment within the river) and the chemical analyses proposed below, additional sampling may be required to define the extent of contamination from the M&H Zinc Company Site. After completion of the habitat characterization discussed in Section 2.5 of the FSP, a benthic sampling program will be developed, as necessary.

Co-located surface-water and sediment samples will be collected from six locations within the Little Vermilion River along the OU1/OU2 boundary. In addition, six sediment samples (with no associated surface-water samples) will be collected in between the co-located samples. Approximate locations of the surface-water and sediment samples are shown on Figure 3 and listed on Table 1. The exact locations of the samples may have to be altered based on the actual presence or absence of sediment in the river at the specific proposed locations.

Two co-located surface-water and sediment samples will be collected from two locations upstream of the Site along the Little Vermilion River. The first location is 100 ft upstream of the 30th Street (Ed Duffy Road) bridge and the second location is 100 ft upstream of the Quarry bridge. The proposed surface-water and sediment samples are shown on Figure 3 and listed on Table 1 and may be altered slightly based on the presence or absence of sediment in the river at the specific proposed locations. The samples are proposed upstream of the bridges in an attempt to minimize potential impacts due to the roadway traffic.

2.3.3 Upland Sediment and Surface-Water Samples

If surface water is present during the RI, one co-located surface-water and sediment sample will be collected from an area to the west of the abandoned ICRR grade (now dirt road) just north of the gate located north of the emergency bypass pond. At this location, on 1 May 2007, a seep was observed emanating from the sinter pile (also referred to the ash disposal area on historic M&H Zinc Company maps). The water seeping out of the sinter was observed to accumulate along both sides of the dirt road with no apparent surface-water flow pathway.

Carus will also observe the OU1 site immediately following a significant rain event to look for additional areas where surface-water flow is present. If noted, up to three co-located surface-water and sediment samples will be collected. Areas to be considered will be based on the surface-water basin analysis discussed in Section 7.8 of the Work Plan

2.3.4 Surface-Water and Sediment Sample Collection Procedures

Surface-water and sediment sampling will follow procedures outlined in SOP No. 300 in the FSP. Water samples will be collected using a decontaminated glass measuring

cup. Sediment samples will entail use of a stainless steel bowl and spoon with either a hand auger or ponar sampler employed if deep water conditions necessitate their use.

At the time of water sample collection, field measurements of temperature, conductivity, DO, turbidity, pH, and ORP will also be recorded at all stations.

2.3.5 Sample Handling and Analysis

Proper field sampling documentation and field analytical and laboratory documentation helps to ensure sample authenticity and data integrity. Section 3.2 of this FSP describes the methods for assigning unique sample names. The unique sample name will be used on the sample containers, sample tags, and Chain-of-Custody Record. Procedures for sample shipping are described in SOP No. 410.

Surface-water samples will be analyzed for TAL metals (USEPA Methods 6010B/6020/7471A), VOCs (USEPA Method 8260B), SVOCs (USEPA Method 8270C), pesticides (USEPA Method 8081A), PCBs (USEPA Method 8082), and cyanide (USEPA Method 9012A). Sediment samples will be analyzed for TAL metals (USEPA Methods 6010B/6020/7471A), VOCs (USEPA Method 8260B), SVOCs (USEPA Method 8270C), pesticides (USEPA Method 8081A), PCBs (USEPA Method 8082), cyanide (USEPA Method 9012A), and AVS/SEM for copper, cadmium, nickel, zinc, and lead. Analyses required for each sample are summarized in Table 1.

Laboratory services will be provided by CAS Rochester, New York.

2.4 Groundwater Investigation

2.4.1 Introduction and Sampling Rationale

As described in detail in the Work Plan, the OUI groundwater flow system consists of several matrices with highly dissimilar characteristics, including Pennsylvanian bedrock, Pleistocene till, Holocene alluvium, fill, and slag. Two specific potential flow pathways (southward flow in the alluvium and eastward discharge of groundwater from the slag into the river) warrant careful characterization, although an understanding of groundwater quality in all media will also benefit the groundwater risk assessment.

In general terms, the goals of the groundwater characterization program can be summarized as follows:

- sufficient groundwater characterization in the two most significant transport media, slag and alluvium;
- sufficient understanding of background conditions, which primarily correspond to bedrock groundwater;
- limited characterization of other media, including fill and Pleistocene till;
- evaluation of vertical gradients among media;
- an analytical sampling program that addresses all analytical parameters while focusing on those of greatest significance (i.e., metals);
- sampling wells of consistent quality to avoid unnecessary variability in sample turbidity or well productivity;
- incorporation of groundwater quality data generated in OU2; and
- representative hydraulic characterization of sampling media.

Hence, the groundwater characterization scope will consist of the following components: (i) reconnaissance and rehabilitation of the existing well network; (ii) installation of additional monitoring wells; (iii) sampling of the expanded well network for a broad suite of analytical methods; (iv) potentiometric mapping, including an evaluation of vertical gradients; and (v) hydraulic characterization. There will be close coordination with SulTRAC on matters pertaining to potentiometric gauging and well survey to ensure that a coherent, sitewide dataset is obtained.

A reconnaissance of the monitoring well network will be performed to evaluate the condition of each well. The full network of existing wells will be redeveloped at a minimum, or replaced as needed, if turbidity cannot be stabilized as discussed in Section 2.4.2. In addition, eleven additional monitoring wells are proposed for installation in the OU1 area, as shown on Figure 4. The additional monitoring wells are proposed to supplement the existing well network because the existing network is not

sufficient to evaluate the horizontal and vertical distribution of hazardous substances, pollutants, or contaminants in the groundwater and to determine the extent, fate, and transport of any groundwater plumes containing hazardous substances, pollutants, or contaminants. The additional wells proposed for the Site are screened in various site media, including slag, shale, and alluvium underlying the slag.

The analytical program for groundwater sampling will include the following analyses in the proportions given:

- TAL metals for all samples;
- VOCs, SVOCs, and cyanide for approximately 25% of samples;
- field parameters (including ferrous iron, sulfide, and alkalinity) for all samples; and
- total organic carbon (TOC), orthophosphate, and sulfate in two background locations and two groundwater samples collected from wells screened within each submedium (e.g., slag, alluvium, fill, etc.).

The analytical program described above is based on the understanding of COPCs observed on-site. All groundwater samples will be analyzed for TAL metals. A subset of groundwater samples will be analyzed for VOCs and SVOCs, as these chemicals are present in lower frequency at the Site than metals. In an effort to more fully understand fate and transport mechanisms, geochemical parameters (TOC, orthophosphate, and sulfate) will also be analyzed; tests for these geochemical parameters are evenly distributed among site media to better understand the influence of a given medium on groundwater geochemistry.

Potentiometric mapping will be performed with the updated well network and in concert with OU2 characterization by SulTRAC. This mapping will refine the understanding of both lateral and vertical groundwater flow directions. Hydraulic characterization through slug testing will be performed on a subset of newly installed wells. This will supplement the existing dataset of hydraulic conductivity data to provide a comprehensive understanding of hydraulic conductivity across all site media; the data so collected will assist in groundwater flow rate computation.

The following sections provide the details of field implementation of the aforementioned tasks.

2.4.2 Monitoring Well Network

The current network of 18 monitoring wells consists of five wells each in bedrock and slag, three wells each in alluvium and till, and two wells in fill. Based on a cursory observation of well conditions in recent site tours, the wells appeared to be in good condition, although it is known that none of the wells has been developed in the last five years. Three of the wells (G101, G103, and G106) are used for routine monitoring.

The proposed well network for the RI/FS, shown in Figure 4, will include 29 wells designed to provide consistent spatial coverage and a representative sampling of site media. This network will include the existing 18 wells plus an additional 11 wells (five in slag, and three each in alluvium and bedrock) designed to complete the spatial coverage and selection of hydrogeologic layers. The ultimate well network will include ten wells screened in slag, eight wells screened in bedrock, six wells screened in alluvium, three wells screened in till, and two wells screened in fill. The proposed number of wells (29) is favorable for purposes of statistical evaluation in the HHRA.

Existing wells in the OU1 area will be evaluated for use as part of a sitewide monitoring network through redevelopment as discussed in Section 2.4.3. Turbidity measurements will be used to identify wells that are suitable for further groundwater investigations. Specifically, for wells undergoing redevelopment, if turbidity readings cannot be stabilized to +/- 10% per the Low Flow Sampling Protocol (SOP No. 110), the turbidity data will be evaluated with respect to magnitude and variability to evaluate whether the well is suitable as a monitoring point. If necessary, replacement monitoring wells will be installed and developed as described in Sections 2.4.4 and 2.4.5 of the FSP.

Existing monitoring wells located within OU1 are listed in Table 3. Procedures for collecting groundwater samples are described in Section 2.4.7 of the FSP. All groundwater samples will be collected in accordance with SOP No. 110 (Groundwater Sampling Using the Low-Flow Protocol).

2.4.3 Well Reconnaissance and Rehabilitation

A monitoring well network reconnaissance will be performed to evaluate the condition of all monitoring wells prior to sampling. Since no wells have been developed in the last five years, all wells will be redeveloped at a minimum, and replaced as needed, if turbidity cannot be stabilized as described above. Controlling turbidity is particularly important for OU1 due to the demonstrated effect of turbidity on metals concentrations. The integrity of the well cap, pad, and locking system will also be evaluated.

Well development methods are described in Section 2.4.5.

2.4.4 Monitoring Well Installation

This section describes procedures for installing monitoring wells and piezometers, which will be installed either through well network expansion as discussed in Section 2.4.2 or rehabilitation as discussed in Section 2.4.3. All wells will be installed in accordance with procedures outlined in Illinois Administrative Code (IAC), Title 77, Chapter I, 920.170. Monitoring wells will be installed in boreholes advanced with either HSA methods for unconsolidated media or by using mud rotary drilling methods or roto sonic methods for bedrock wells. Procedures for the installation of monitoring wells are described in detail in SOP No. 120.

Well casings for monitoring wells will consist of two-inch diameter, flush-threaded, polyvinyl chloride (PVC) materials. In wells less than 100 ft in depth, Schedule 40 PVC well casings and screens will be used. In wells deeper than 100 ft, Schedule 80 PVC well casings and screens will be used. Well screens for monitoring wells will be ten ft in length, and wells screens for piezometers¹ will be five ft in length. All well screens will have a slot size of 0.010-inches with a slot spacing of 0.125 inches.

For bedrock well installation, 8-inch diameter steel surface casing will be grouted into bedrock prior to PVC installation in order to isolate the bedrock sampling horizon.

¹ Piezometers will only be installed if the primary purpose is potentiometric measurement as opposed to analytical sampling.

A silica-based, sand filter pack will be placed by gravity in the annular space surrounding the well screen and extend a minimum of six inches below the bottom of the well screen and two ft above the top of the well screen. A filter pack seal (or choke) consisting of fine sand will be placed by gravity to a minimum of two ft above the sand filter pack; the purpose of the choke is to prevent infiltration of bentonite from the seal (described next) into the screened interval. A minimum of two ft of bentonite chips will be installed above the choke to seal the screened interval. If the seal is above the water table, it will be hydrated through the addition of water. A high-solids grout (bentonite slurry) will be tremmied in place to seal the annular space. The ground surface seal will consist of native soil or cement. Between all steps of monitoring well installation, a weighted measuring tape will be used to confirm that the appropriate depths have been reached.

New wells will be developed as described in Section 2.4.5.

2.4.5 Monitoring Well Development

Wells will be developed using decontaminated or dedicated sampling equipment to reduce the possibility of cross-contamination. Purge water collected during well development will be containerized and disposed of as described in Section 5. Procedures for monitoring well development are described in SOP No. 130.

Note that all existing monitoring wells will be redeveloped since they have not been redeveloped within the last five years. The current inventory of existing monitoring wells and piezometers is provided in Table 3. This table presents information for each well and piezometer, including installation date, elevation data, and the geologic horizon in which each well or piezometer is screened. The geologic horizon refers to the various lithologic units documented at the Site during previous investigations.

2.4.6 Monitoring Well/Borehole Abandonment

Any boreholes or wells designated for abandonment will be abandoned in accordance with IAC Section 920.120 requirements. Monitoring well materials will be removed by overdrilling. Boreholes will be abandoned by the complete filling of the borehole with bentonite granules, bentonite chips, or bentonite grout. A tremmie pipe will be used to deliver sealing materials in boreholes and wells that are greater than 30 ft in depth or with standing water. Procedures for borehole abandonment are described in SOP No. 140.

2.4.7 Groundwater Sample Collection Procedures

2.4.7.1 Sampling Equipment

Each well will be purged with either a decontaminated submersible or bladder pump or a peristaltic pump. Tubing will be dedicated to the well. Field measurements for specific conductance, pH, temperature, oxidation-reduction potential (ORP), turbidity, and dissolved oxygen (DO) will be taken at the time of sample collection. The procedures for measuring groundwater field parameters and operating the equipment are detailed in SOP No. 110. A comprehensive list of sampling equipment needed to collect groundwater samples is also listed in SOP No. 110.

2.4.7.2 Sample Collection

Groundwater samples will be collected from existing and proposed monitoring wells located within OU1. Prior to sample collection, static water levels will be measured in all site wells with a water level indicator. The procedures for using the water level indicator are described in SOP No. 100. Samples will be collected per the low-flow sampling protocol described in SOP No. 110. Field-measured parameters must stabilize for purging to be complete. At least three consecutive readings spaced approximately five minutes apart must be within the following ranges for the following indicator parameters:

<u>Indicator Parameter</u>	<u>Acceptable Range</u>
Specific Conductance	±3% micromhos per centimeter (µmhos/cm)
pH	±0.1 pH units
Temperature	±10%
DO	±10% milligrams per liter (mg/L)
ORP	±10% millivolts (mV)
Turbidity	±10% nephelometric turbidity units (NTUs)

Purge volumes and color, odor, and turbidity of the groundwater in each monitoring well will be noted on the Low-Flow Sampling Protocol field form. The condition of the well will also be recorded at the time of sample collection. The procedure for collecting groundwater samples is also described in detail in SOP No. 110. All details regarding

subsurface groundwater sample collection will be recorded in the field form accompanying the SOP.

2.4.7.3 Sample Containerization

Groundwater samples will be placed in appropriate laboratory-supplied containers. Samples will be placed in containers and preserved in accordance with SOP No. 110 and the analytical requirements summarized in Table 2.

2.4.8 **Sample Handling and Analysis**

Proper field sample identification helps to ensure sample authenticity and data integrity. Section 3.2 of this FSP describes the methods for assigning unique sample names. The unique sample name will be used on the sample containers, sample tags, and Chain-of-Custody Record. Procedures for sample shipping are described in SOP No. 410.

Groundwater samples will be analyzed for target parameters using the following methods: TAL metals (USEPA Methods 6010B/6020/7471A), VOCs (USEPA Method 8260B), SVOCs (USEPA Method 8270C), pesticides (USEPA Method 8081A), arsenic and manganese (USEPA Method 6020), iron (USEPA Method 6010B), and cyanide (USEPA Method 9012A). Samples will also be analyzed for specialty parameters to evaluate groundwater geochemistry, including TOC (USEPA Method 9060), orthophosphate (USEPA Method 300.0/9056), and sulfate (USEPA Method 300.0/9056). Additionally, field kit measurements of ferrous iron, sulfide, and alkalinity will be performed.

Laboratory services will be provided by CAS, Rochester, New York.

2.4.9 **Hydraulic Testing**

Of the 18 existing monitoring wells, 11 have undergone hydraulic testing via slug or pump testing; these include four bedrock wells, one slag well, three alluvial wells, two till wells, and one fill well. Of the new monitoring wells, four slag wells will undergo slug testing. This will ensure that at least half of the monitoring wells from each medium will have associated hydraulic conductivity data.

Slug testing will be performed according to SOP No. 150 in Appendix D. Because slug

testing in high-permeability media, such as slag, can lead to imprecise results, pump testing may be preferred; hence, SOP No. 160 for pump testing has been included as a contingency in the event that slug testing does not yield appropriate data.

2.5 Habitat Characterization

The SLERA (described in greater detail in Section 7.7 of the Work Plan) will rely on an initial field component of habitat characterization. As an early step in screening-level problem formulation, fundamental knowledge of the potential environmental setting (representative habitats and wildlife) at a site must be documented. As such, the habitat characterization will be performed as a preliminary site ecological survey concurrent with the analytical characterization components of the work plan.

The goal of the habitat characterization is to identify and characterize the current and potential threats to the natural environment from hazardous substance release. Habitat characterization of OUI will identify habitat types occurring on the Site, probable pollutant transport routes, and possible indicator species or a species population to serve as the focus of the study, as warranted. Threats to the environment include not only existing adverse ecological impacts, but also the risk of such impacts in the future.

Habitat characterization will consist of a review of available data and a site visit. Current information on ecological resources of the Site, including jurisdictional wetlands, sensitive habitats, and protected species will be sought from State and Federal natural resource agencies, including the USGS, Illinois Natural Heritage Program, State Game and Fish Departments, and U.S. Fish and Wildlife Service National Wetlands Inventory. Information including topographic and recent aerial maps will be used in the canvassing of site habitat information. Following the review of current, available information, personnel qualified in ecological assessment will conduct a site visit to identify and describe natural areas (e.g., upland forest, on-site stream, or nearby wildlife refuge) and disturbed/man-made areas (e.g., lagoons). Direct observations of dominant plants and wildlife (especially any occurrence of protected species), including animals signs in the form of middens, nest, tracks, burrows, droppings, calls, etc., will be documented during the site visit. The combination of desktop study and site visit will result in a habitat characterization providing a description of habitats present on-site including those that may be potentially contaminated or otherwise disturbed.

This information will be used to assist in the refinement of assessment endpoints for the ecological risk assessment described in Section 7.7 of the Work Plan.

2.6 Ambient Air Sampling

As part of the HASP and the HHRA for the RI/FS, ambient air sampling for selected metals in particulates and asbestos will be performed during intrusive operations in the slag pile area. The need for ambient air concentrations for metals was identified as part of the HASP development; metals data will be used to support decisions concerning ongoing levels of respiratory protection during intrusive operations. Separately, asbestos data will be considered as a component of the HHRA for the Site.

2.6.1 Sample Location and Frequency

Ambient air samples for lead and arsenic will be collected in workzone locations during the first two days of intrusive operations at the slag pile. Sampling pumps will be placed at two locations (upwind and downwind) in relation to the equipment in use at a distance of 10 to 20 ft. If metals concentrations are below one half of the most stringent occupational standard (OSHA and American Conference of Industrial Hygienists (ACGIH) values to be considered, shown in Table 4), then personal protective equipment (PPE) will be downgraded to Level D protection for the remainder of the RI/FS. If concentration levels are greater than one half of the most stringent standard, then intrusive operations will continue in Level C protection. Additional sampling will be performed at Geosyntec's discretion to evaluate whether a sufficient database of ambient air data can be generated to support a downgrade. Rain-free sampling days after relatively dry conditions will be selected to avoid a low bias in the sampling results. If wet conditions are persistent, the test will be repeated if drier and/or windier conditions become typical at a later time.

The asbestos data will be collected for use in the HHRA and will not be used as an indication for downgrading PPE. Dust suppression measures will be used to control fugitive dust emissions, including asbestos-bearing emissions, during activities which may generate dust (e.g., trenching and drilling). Air samples for asbestos will be collected from three locations in the slag pile trenching component of the solid matrix characterization program. The three locations will be in trenches in slag closest to OU2, the most likely source of airborne asbestos emissions.

2.6.2 Ambient Air Sample Collection Procedures

Ambient air sampling will follow procedures outlined in SOP No. 500. Samples will be collected using high-volume sampling pumps and filters media provided by the laboratory. It is critical that sample volume be recorded in the field documentation in order to convert the analytical results from units of mass on filter to concentration.

At the time of sample collection, weather conditions will be noted in detail, because they will have a profound effect on sample results.

2.6.3 Sample Handling and Analysis

Proper field sampling documentation and field analytical and laboratory documentation helps to ensure sample authenticity and data integrity. Section 3.2 of this FSP describes the methods for assigning unique sample names. The unique sample name will be used on the sample containers, sample tags, and Chain-of-Custody Record. Procedures for sample shipping are described in SOP No. 410.

Ambient air samples will be analyzed for arsenic and lead by USEPA Method 6010B and asbestos by National Institute for Occupational Safety and Health (NIOSH) Method 7400.

Laboratory services will be provided by STL Laboratories of Knoxville, Tennessee for metals and by Materials and Chemistry Laboratory, Inc. of Oak Ridge, TN for asbestos.

2.7 Field Quality Assurance/Quality Control Samples

Quality Assurance/Quality Control (QA/QC) samples are typically collected in the field and submitted to the laboratory along with other environmental samples to evaluate field and laboratory precision and accuracy. Evaluation of QA/QC sample results allows for the quality of the data to be assessed as part of the overall project QA. The six types of QA/QC samples are as follows:

- trip blanks;
- equipment rinsate blanks;
- field blanks;

- filter blanks;
- duplicates; and
- matrix spike/matrix spike duplicates (MS/MSDs).

Trip blank, equipment rinsate blank, filter blank, and field blank samples are used to assess field conditions during sample collection and transport. Duplicates and MS/MSD samples are replicate samples used to help assess laboratory precision and accuracy. Section 3.2 of this FSP describes the methods for assigning unique sample names. The unique sample name will be used on the sample containers, sample tags, and Chain-of-Custody Record. Samples will be placed in laboratory-supplied containers and preserved in accordance with the analytical requirements summarized in Table 2. One temperature blank will also be included with every shipping container from the laboratory to ensure that the samples arrive at acceptable temperatures.

The required frequency of QA/QC samples is summarized in Table 5.

2.7.1 Trip Blanks

Trip blanks are filled with reagent grade water at the laboratory, shipped to the Site with the empty sample containers, and returned to the laboratory with the filled sample containers. Trip blanks are used to determine if VOC samples have been cross-contaminated during shipping and handling.

Trip blanks will be included with each shipping container that contains solid or groundwater samples to be analyzed for VOCs.

2.7.2 Equipment Rinsate Blanks

Equipment rinsate blanks will be collected following decontamination of sampling equipment (e.g., bowls, spoons, hand augers, knives). One equipment rinsate sample will be collected for every 20 samples submitted to the laboratory with a minimum of one equipment rinsate sample collected per sampling crew per day. Following decontamination of the equipment, deionized water will be poured over selected sampling equipment and collected for laboratory analysis. The equipment rinsate samples will be analyzed for the same methods used for field samples that day.

2.7.3 Field Blanks

Field blanks are samples of source water used for decontamination. One field blank sample will be collected for each source of water used for decontamination. Field blanks will be analyzed for VOCs and metals.

2.7.4 Duplicate Samples

Duplicate samples are samples of selected solid, groundwater, surface-water, and sediment sample locations that are split samples collected in the field. Duplicate samples will be collected at a frequency of one sample for every 20 investigative samples submitted for laboratory analysis. Duplicate samples are collected after sample homogenization to evaluate the effectiveness of the homogenization protocol. An important exception to this is with VOCs; VOC duplicate aliquots are sampled directly from their source without homogenization to avoid VOC loss due to volatilization.

2.7.5 Matrix Spike/Matrix Spike Duplicate Samples

MS/MSD samples are replicate samples that are spiked with a known concentration of COPCs which are then measured as they would be for field samples; the results are used to determine laboratory precision and accuracy. One MS/MSD sample will be collected for every 20 investigative samples submitted for laboratory analysis. The volume of sample collected at each of the locations where MS/MSD samples will be obtained is triple the routine volume: the first aliquot serves as the field sample, the second aliquot as the MS, and the third as the MSD. An exception is with solid/sediment matrix samples for metals; in this case, only double sample volume is required.

2.8 Field Surveying

2.8.1 Horizontal and Vertical Control

All RI sample locations will be surveyed by a State of Illinois registered land surveyor or by Geosyntec personnel using a GPS unit with sub-meter accuracy. Horizontal control is based on Illinois State Plane - East, North American Datum (NAD) of 1983. A registered land surveyor is required for monitoring well top of casing elevations. Elevation measurements are based on National Geodetic Vertical Datum (NGVD) of 1929. This coordinate system will be used for establishing horizontal and vertical

control to sampling data. For each monitoring well location, the top of the PVC well casing and the ground surface will be surveyed for horizontal and vertical control. For each solid sample, the ground surface will be surveyed for horizontal and vertical control.

2.8.2 Data Acquisition

A minimum of two control points will be established at the Site upon which the State Plane coordinates and elevation are set. These points will be established in a permanent location where they will not be disturbed.

Measured elevations will be tied to existing site control points, and referenced to NGVD of 1929 elevations. Measured horizontal locations will be tied to the existing site control points in the Illinois State Plane – East system. Horizontal orientation locations will be accurate to ± 0.1 ft and vertical orientation elevations accurate to ± 0.01 ft.

3. DOCUMENTATION, SAMPLE PACKING, AND SHIPPING

3.1 Field Documentation

Field visits and sample collection programs are documented using a combination of field log books and specific field log forms. These two methods have their advantages and disadvantages, as follows:

- Field log books have the advantage of maintaining work chronology. Since all pages and lines are used in sequence without any skips, it is possible to reconstruct the sequence of work in the event that any quality issues or other incidents arise. One log book can be used to document several weeks' worth of work in sequence depending upon the nature of the work. In addition, since log books lack structure, they provide flexibility in that they can be used to document nearly any site work; however, the lack of structure in log books is a disadvantage for record-intensive work, such as groundwater sampling, because the lack of entry boxes for field parameters discourages consistent data collection.
- Conversely, field forms have the advantage of customization (e.g., a groundwater sampling form can be designed in detail to remind the field team member to record a list of specific readings). Field forms are valuable for large sampling events in which consistency in the method of recording observations is desired. They have the disadvantage of lacking weatherproofing or any degree of chronological sequence. They are also not as portable or durable as log books.

A log book will be in use for all visits to the Site, ranging from brief site walks to major, multi-week characterization programs. If the work is short in duration (e.g., less than one day) and irregular or *ad hoc* in nature (i.e., a task that is not captured by a standard field form), then all of the work shall be documented in the log book. Conversely, if the site visit is longer in duration and more repetitive (e.g., a major groundwater or solid sampling event), corresponding field forms will be used for documentation of each sample, whereas the log book will be used to document a summary of the day's activities and non-repetitive tasks, including the following:

- time of arrival and departure from the Site, including lunch breaks;
- names of field team members;
- time of arrival and departure of subcontractors;
- the nature of the daily health and safety tailgate meeting, with signatures of all participants;
- instrument calibration;
- supply deliveries;
- weather;
- interaction with agency or client personnel;
- incident occurrence and management; and
- any other irregular or ad hoc activities.

As such, the log book(s) will provide a comprehensive overview of all site activities throughout the RI/FS; the level of detail of documentation within each log book entry will depend upon the duration of an individual visit and the applicability of field forms to the tasks performed.

3.1.1 Details of Log Book Use

Sampling personnel will use a bound field log book with moisture-resistant pages to record pertinent field information with waterproof ink. The log book will identify the project name, project number, and geographic location of the Site; it will also indicate the name and mobile telephone number of the Field Manager in the event that the log book is lost and recovered. Daily field activities and sampling information will be entered in the log book on serially-numbered pages. At the end of each day's entries, sample collection personnel shall sign and date the entry. Corrections will be made to entries with initialed and dated line-out deletions. A diagonal line will be drawn across the remaining blank space of the last page of each day's entry. All log book lines will

be used in sequence, and no blank lines shall remain at the end of the day. All observations will be recorded in sequence.

Multiple log books will be required over the course of the RI/FS. It is desirable to have a continuous sequence of log books throughout the course of the project, with one log book in use at any one time. Upon completion of a log book, the timeframe covered will be clearly indicated on the front cover and spine by noting the date range of work and investigative phase name. In some cases, however, the presence of multiple field teams may require the use of two log books in parallel. In these cases, the Field Manager shall maintain the primary log book. The secondary log book shall be clearly identified as such and shall make reference to the primary log book on or inside its front cover. It shall only be used to record observations made away from the Field Manager.

3.1.2 Field Forms

As discussed in Section 3.1, field forms shall be used for specific field sampling tasks of a routine and repetitive nature, such as solid sampling, well purging, or well installation. Field forms have the advantage of prompting the user for detailed data documentation in a consistent format.

Attachment C includes the following field form templates for various field tasks to be conducted during the RI/FS:

- Daily Field Report;
- Photographic Documentation Log;
- Daily Health and Safety Report;
- Water Level Measurement Field Form;
- Groundwater Sampling Form;
- Meter Calibration Report;
- Well Completion Information Form;
- Well Development Form;

- Well Inspection & Slug Test Form;
- Step Drawdown Test Form;
- Soil (Solid) Sampling Record;
- Lithologic Log; and
- Surface-Water and Sediment Sampling Record.

The protocol for form completion will be similar to those of log books:

- one form will be filled out per sample;
- corrections shall be made through single-line strikeout with initial and date; and
- tables within forms (e.g., field parameters during well purging) shall be filled out with each line in sequence; no lines will be skipped, and unused lines at the end of sample collection shall be crossed out, initialed, and dated.

3.2 Sample Nomenclature

3.2.1 Field Sample Nomenclature

The sample identification scheme for field sample collection will utilize a three-letter project identification code followed by a sample type code, location code, and depth or date details. The general form is as follows:

OU1-aa-bbbbbb(-yymm(dd))(-D1-D2), where identification components are described below.

OU1 will be used for the OU1 RI to differentiate samples and locations from those of the OU2 RI/FS.

“aa” is the matrix code or sample type code, which will correspond to the sample type as follows:

- AA: ambient air;
- DC: drill cuttings for disposal;
- GW: groundwater samples from monitoring wells;
- SE: sediment samples;
- SS: solid matrix samples (e.g., soil, slag, sinter, etc.);
- SW: surface-water samples;
- PW: purge water for disposal; and
- DW: decontamination water.

“bbbbbb” is the location code, which will follow the sample type code and will consist of up to six characters that indicate the sample location. Hyphens will be omitted. For groundwater samples, the location code will be the monitoring well number. Solid, sediment, and surface-water samples will use the location identifications (IDs) shown on sample location figures.

(-yymm) is only used (without parentheses) for samples where resampling at a given location may occur. It is assumed that this will include ambient air, groundwater, surface-water, and sediment-related locations. If a sample location is resampled in the same month, the sample ID will include the day of the month as well (-yymmdd). Note that any single digit months or days will include a leading “0”.

(-D1-D2) is only used (without parentheses) for solid samples, because depth is a critical sample differentiator. Examples of sample identification numbers include:

- OU1-GW-P1-0705, for OU1, groundwater sample from monitoring well P-1 in May 2007;

- OU1-SS-SB301-2-4, for OU1, solid sample from DPT Soil Boring 301 at a depth of 2 to 4 ft BLS;
- OU1-SW-LVR211-0705, for OU1, surface-water sample from Little Vermilion River Location 211 in May 2007;
- OU1-SE-LVR211-0705, for OU1, sediment sample from Little Vermilion River Location 211 in May 2007; and
- OU1-AA-SB301N-070525, for OU1, ambient air sample from the north side of SB-301 workzone on 25 May 2007 (date characteristics indicate that location was previously sampled in the same month).

3.2.2 Quality Assurance/Quality Control Sample Nomenclature

QA/QC samples will have a blind naming system to ensure that they are treated the same way as field samples are treated. For all QA/QC samples, use the following fictitious locations, each of which indicates a type of QA/QC sample. If multiple QA/QC samples are collected on a given day, append A, B, C, etc. in sequence to the fictitious location name.

The fictitious locations are as follow:

- for equipment blanks, use MW-401;
- for trip blanks, use MW-402;
- for filter blanks, use MW-403;
- for water matrix duplicates, use MW-404, and for solid matrix duplicates, use SB-406; and
- for field blanks, use MW-405.

For blank samples, the matrix identifier (“aa” in the formula above) will be “SW” in order to have the appearance of a field sample. Sample IDs for duplicate samples will carry the matrix of the parent sample.

Because the sample ID gives no parent sample information for field duplicates, it is imperative that field documentation record this information so that parent/duplicate data pairings are available after analytical data have been received. For MS/MSDs, use the same sample ID as the parent sample and indicate “MS/MSD” in the comment field on the Chain-of-Custody Record.

3.3 Sample Packing and Shipping – Field Procedures

3.3.1 Hold Times

The first step in proper sample handling and custody is observance of analytical holding times, which can vary from 24 hours to 180 days depending upon the analytical method(s) selected for the samples. Knowledge of required holding times will have a direct impact on scheduling of sample collection, packing, and shipping activities. The sample container, volume, preservation, and holding times applicable to each analytical method are shown in Table 2.

3.3.2 Sample Custody

Sample collection and sample custody procedures are designed so that field custody of samples is maintained and documented. These procedures provide identification and documentation of the sampling event and the sample chain-of-custody from shipment of sample bottleware, through sample collection, to receipt of the sample by the subcontracted laboratory. When used in conjunction with the laboratory’s custody procedures and the sample bottleware documentation, these data establish full legal custody and allow complete tracking of a sample from preparation and receipt of sample bottleware to sample collection, preservation, and shipping through laboratory receipt, sample analysis, and data validation. The chain-of-custody is defined as the sequence of persons who have the item in custody.

Field custody procedures are described below. Sample collection procedures concerning sample identification and documentation, field log book, sample containers, sample packing, and sample shipping are described.

The persons responsible for sample custody, and a brief description of their duties, are as follows:

- **Laboratory Sample Custodian or Commercial Supplier:** Verifies that the bottleware is certified clean; arranges for bottleware shipment to field sampling personnel or the contractor's equipment shop.
- **Field Staff:** Receives sample bottleware from laboratory, inspects bottleware for physical integrity; retains shipping invoice or packing list from shipping courier as documentation of transfer of bottleware; collects and preserves samples; retains bottleware and samples under custody until sample shipment; relinquishes samples to shipping courier or to lab representative.
- **Laboratory Project Manager (LPM):** Verifies reported laboratory analyses to the sample Chain-of-Custody Record; assures that chain-of-custody documentation is incorporated into the project file.

A sample or other physical evidence is in custody if it is:

- in the field investigator's, transferee's, or lab technician's actual possession; or
- in the field investigator's, transferee's, or lab technician's view, after being in his/her physical possession; or
- in the field investigator's, transferee's, or lab technician's physical possession and then he/she secured it to prevent tampering; or
- placed in a designated secure area.

3.3.3 Chain-of-Custody Record

The field Chain-of-Custody Record is used to record the custody of all samples or other physical evidence collected and maintained. This form shall not be used to document the collection of split or duplicate samples. The Chain-of-Custody Record also serves as a sample logging mechanism for the analytical laboratories' sample custodian.

The following information must be supplied in the indicated spaces in detail to complete the field Chain-of-Custody Record:

- project-specific information, including the project number and project name;
- signatures of all samplers and/or the sampling team leader in the designated signature block;
- sampling station number, date, and time of sample collection, grab or composite sample designation, and sample preservation type included on each line (each line shall contain only those samples collected at a specific location);
- sampling team leader's name recorded in the right or left margin of the Chain-of-Custody Record when samples collected by more than one sampling team are included on the same form;
- total number of sample containers listed in the indicated space for each sample and the total number of individual containers for each type of analysis under the indicated media or miscellaneous columns (note that it is impossible to have more than one media type per sample);
- sample volume (for air samples only);
- documentation of the transfer of samples listed on the Chain-of-Custody Record by the field investigator and subsequent transferee(s) in the spaces provided at the bottom of the form (both the person relinquishing the samples and the person receiving them must sign the form; provide the date and time that this occurred in the proper space on the form; and usually, the last person receiving the samples or evidence should be a laboratory sample custodian); and
- air bill numbers or registered or certified mail serial numbers recorded in the remarks column at the bottom of the form.

The Chain-of-Custody Record is a serialized document. Once the Chain-of-Custody Record is completed, it becomes an accountable document and must be maintained in the project file. The suitability of any other form for chain-of-custody should be evaluated upon its inclusion of all of the above information in a legible format. Examples of Chain-of-Custody Records for each laboratory described in this document are provided as Attachment A.

3.3.4 Sample Packing and Shipping

Samples are packed for shipping in waterproof ice chests and coolers. Depending upon container type, the sample containers may be individually sealed in Ziploc® or other similar plastic bags, prior to packing them in the cooler with bubble wrap or Styrofoam packing. Wet ice will be double-bagged in plastic bags (to inhibit cross contamination of samples by melt water) and placed with the samples in the cooler to maintain the samples at a temperature of 4 +/- 2 degrees Celsius during shipping. Note that samples for analysis by XRD and for metals in particulates do not require preservation; they can be sent at ambient temperature.

The Chain-of-Custody Record that identifies the samples is signed as "relinquished" by the principal sampler or responsible party. This Chain-of-Custody Record is sealed in a waterproof plastic bag and is placed inside the cooler, typically by taping the bag to the inside lid of the cooler.

Following packing, the cooler lid is sealed with packing tape. A custody seal is signed, dated, and affixed from the cooler lid to the cooler body, and is additionally covered with clear tape. This ensures that tampering with the cooler contents will be immediately evident.

The sample coolers are typically shipped by overnight express courier to the laboratory. A copy of the shipping invoice is retained by the Field Manager and becomes part of the sample custody documentation.

4. DECONTAMINATION

4.1 Standard Procedures

Decontamination of sampling equipment will take place either at sampling locations or in a centralized area. Decontamination of drilling equipment and tools will be conducted in a centralized area to improve management of decontamination liquids. Prior to arrival on-site, all downhole drilling equipment will be pressure-washed. Equipment used for drilling and sampling will be decontaminated prior to each use and in accordance with the cleaning procedures presented in Section 4.

A decontamination area for sample preparation equipment will be established within or near the boundary of the EZ. The EZ is defined as the area where contamination is either known or likely to be present, or because of activity, will potentially harm personnel. Entry into the EZ requires the use of PPE.

A personnel decontamination station will be established outside and adjacent to the EZ. All personnel will proceed through the appropriate contamination reduction sequence upon leaving the EZ. All PPE will be left on-site during any breaks after performing decontamination procedures.

4.2 Sampling Equipment Decontamination Procedures

The following steps outline the decontamination protocol for sampling equipment:

- tap water wash with non-phosphate soap (e.g., Alconox);
- tap water rinse;
- distilled water rinse;
- rinse with 10% nitric acid (only for samples to be analyzed for metals);
- deionized water rinse;
- methanol rinse (only for samples to be analyzed for organics);
- deionized water rinse;

- air dry (completely); and
- aluminum foil wrap.

4.3 **Heavy Equipment**

Because heavy equipment pieces are much larger than sampling equipment and generally come in less direct contact with sampling aliquots, a modified decontamination procedure is appropriate. The following steps outline the decontamination protocol for heavy equipment:

- heavy equipment and all support equipment will be free from excess grease, oils, and caked-on solids from previous work prior to work commencement;
- equipment or materials not used immediately after decontamination will be placed on a plastic sheet, covered with plastic or aluminum foil, or properly secured in or on the drilling rig to avoid potential contamination; and
- excavator buckets, augers, and any other equipment that will enter the borehole will be pressure-washed with a high-pressure system on a decontamination pad prior to advancing each borehole or trench.

Clean, disposable gloves will be worn while handling sampling equipment or downhole tools during the final stages of decontamination. Deionized water will be stored in high-density polyethylene (HDPE) containers and applied via HDPE squeeze bottles or decanted directly from their storage containers.

4.4 **Persistent Contamination**

In some instances, equipment will become contaminated with substances that cannot be removed by normal decontamination procedures. A strong detergent (e.g., Alconox or other industrial grade detergent) may be used to remove such contamination from equipment if it does not destroy or degrade the equipment.

4.5 Disposal of Contaminated Materials

All disposable and single-use materials and equipment used for decontamination must be disposed of properly. Clothing, tools, buckets, brushes, and all other equipment that is contaminated must be secured in drums or other containers and labeled.

5. MANAGEMENT OF INVESTIGATION-DERIVED WASTES

Solid and liquid waste will be tested for the Resource Conservation and Recovery Act (RCRA) TCLP waste profiling followed by disposal to RCRA Subtitle D or C facilities as needed. TCLP analyses will be performed per the requirements of the receiving facility; Table 2 lists the TCLP analytical groups to be used, as needed. In such cases, waste will be managed according to USEPA's 1992 document "Guide to Management of Investigation-Derived Wastes". This document cites numerous applicable or relevant and appropriate requirements (ARARs), including certain definitions of hazardous waste (40 Code of Federal Regulation (CFR) 261.31-33), storage requirements for hazardous wastes (40 CFR 260.10), and Department of Transportation (DOT) regulations for hazardous waste (49 CFR 100-199).

5.1 Identification of Investigation-Derived Waste Streams

Four sources of IDW have been identified for the Site RI:

- drilling spoil (cuttings) from the installation of soil borings and monitoring well borings;
- groundwater purged from monitoring wells and piezometers resulting from well development and groundwater sample collection activities;
- decontamination wastes from waste fluids generated during decontamination of field equipment, sampling equipment, and PPE; and
- PPE from disposable items (e.g., gloves, Tyvek® suits, etc.) used to implement the health and safety program for the RI.

5.2 Drilling Spoils

Drilling spoil is generated during the advancement of borings to obtain solid samples, and borings advanced to install monitoring wells and piezometers. Drilling spoil will be handled as a waste product. Soil borings and monitoring well borings will be installed using HSA, mud rotary, roto sonic, or DPT methods. If drilling mud is generated, it will be solidified by adding Portland cement or powdered bentonite and classified as drilling

spoil. The procedures for handling drilling spoil will include local accumulation at the drilling site, containerization of the drilling spoil, temporary storage of the waste in a secure area, waste profiling, and making arrangements for the transportation and off-site disposal of the waste. Each container will be clearly labeled with the information necessary to identify the source area(s) of the drilling spoil and the dates of accumulation. Filled containers will be temporarily stored at the main plant area, located at 900 Sterling Street. This area is secured by a fence and locked gates to prevent access. Drilling spoils will be transported off-site for disposal. All drilling spoils will be profiled and characterized prior to off-site transport and disposal. A composite sample of the drilling spoils will be collected and submitted for laboratory analysis. The facility manager of the receiving facility will determine what analyses may be required to complete the waste profile.

5.3 Well Development and Purge Water

Purge water generated from well development and groundwater sample collection activities will be handled as a waste product. The procedures for handling development and purge water will require the collection of this water at the monitoring well location in a bulk storage container. All development and purge water will then be transported for off-site treatment and disposal, or alternatively, disposed of on-site at the Carus treatment plant, assuming appropriate permits and approvals are secured. When not in use, the bulk storage container will be stored; this area is secured by a fence and locked gates to prevent access. The bulk storage container should be inspected prior to use to assure it does not leak. If a leak is observed, the container will be repaired or replaced.

5.4 Decontamination Wastes

Wastes associated with the decontamination of field equipment will consist primarily of liquids, with minor amounts of solids. The wastes will be generated by the cleaning of:

- soil boring and sampling equipment;
- heavy equipment (e.g., drill rig, backhoe);
- monitoring well and piezometer development equipment; and
- personnel exiting the EZ around each sampling location.

Following generation, decontamination water will be placed in a bulk storage container. The decontamination water will be decanted during transfer to the bulk storage container to minimize the amount of solids transferred. Solids present after decanting will be placed in drums and treated as drilling spoils. The decontamination water will be disposed of at an off-site treatment facility, or alternatively, disposed of on-site at the Carus treatment plant, assuming appropriate permits and approvals are secured. Procedures for disposal of decanted decontamination water will be the same as disposal of development and purge water.

5.5 Personal Protective Equipment

Waste PPE will be generated during RI activities. Spent waste PPE should be placed in a sealed 55-gallon drum and co-mingled with drilling spoils.

6. SCHEDULE

A schedule for RI/FS tasks is discussed in the Work Plan.

TABLES

Table 1. Sampling Information for Solid, Air, Surface-Water, Sediment, and Groundwater Sampling
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample ID	Matrix	Location	Depth or Stratum	TAL Metals	VOCs	SVOCs	Pesticides	PCBs	Cyanide	Asbestos	TAL Metals SPLP	Soil pH	SEP	NRD	AVS/SEM	TOC	Orthophosphate	Sulfate	Field Parameters		
																			Ferrous Iron	Sulfide	Alkalinity
OUI-SS-SB301-0-1	Slag/Soil	SB-301	0-1 ft BLS	x	x	x	x	x	x		x	x	x	x							
OUI-AA-SB301	Ambient Air		0-1 ft BLS							x											
OUI-SS-SB301-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB301-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB302-0-1	Slag/Soil	SB-302	0-1 ft BLS	x																	
OUI-AA-SB302	Ambient Air		0-1 ft BLS							x											
OUI-SS-SB302-D1-D2	Slag		5 ft Above Water Table	x	x	x			x		x	x	x	x							
OUI-SS-SB302-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB303-0-1	Slag/Soil	SB-303	0-1 ft BLS	x			x	x													
OUI-SS-SB303-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB303-D1-D2	Slag		5 ft Below Water Table	x	x	x			x		x	x	x	x							
OUI-SS-SB303-D1-D2	Soil		Alluvium	x							x	x	x	x							
OUI-SS-SB304-0-1	Slag/Soil	SB-304	0-1 ft BLS	x							x	x									
OUI-AA-SB304	Ambient Air		0-1 ft BLS							x											
OUI-SS-SB304-D1-D2	Slag		5 ft Above Water Table	x										x							
OUI-SS-SB304-D1-D2	Slag		5 ft Below Water Table	x	x	x			x												
OUI-SS-SB305-0-1	Slag/Soil	SB-305	0-1 ft BLS	x			x	x													
OUI-SS-SB305-D1-D2	Slag		5 ft Above Water Table	x							x	x									
OUI-SS-SB305-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB306-0-1	Slag/Soil	SB-306	0-1 ft BLS	x	x	x			x												
OUI-SS-SB306-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB306-D1-D2	Slag		5 ft Below Water Table	x							x	x									
OUI-SS-SB307-0-1	Slag/Soil	SB-307	0-1 ft BLS	x			x	x				x	x								
OUI-SS-SB307-D1-D2	Slag		5 ft Above Water Table	x	x	x			x												
OUI-SS-SB307-D1-D2	Slag		5 ft Below Water Table	x																	
OUI-SS-SB308-0-1	Slag/Soil	SB-308	0-1 ft BLS	x																	
OUI-SS-SB308-D1-D2	Slag		5 ft Above Water Table	x							x	x									
OUI-SS-SB308-D1-D2	Slag		5 ft Below Water Table	x	x	x			x												
OUI-SS-SB309-0-1	Slag/Soil	SB-309	0-1 ft BLS	x			x	x													
OUI-SS-SB309-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB309-D1-D2	Slag		5 ft Below Water Table	x							x	x									
OUI-SS-SB309-D1-D2	Soil		Alluvium	x	x	x			x		x	x									
OUI-SS-SB310-0-1	Slag/Soil	SB-310	0-1 ft BLS	x								x									
OUI-SS-SB310-D1-D2	Slag		5 ft Above Water Table	x																	
OUI-SS-SB310-D1-D2	Slag		5 ft Below Water Table	x	x	x			x												
OUI-SS-SB311-0-1	Soil	SB-311	0-1 ft BLS	x	x	x	x	x	x					x	x						
OUI-SS-SB311-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB312-0-1	Soil	SB-312	0-1 ft BLS	x																	
OUI-SS-SB312-2-4	Soil		2-4 ft BLS	x	x	x	x	x	x												
OUI-SS-SB313-0-1	Soil	SB-313	0-1 ft BLS	x																	
OUI-SS-SB313-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB314-0-1	Soil	SB-314	0-1 ft BLS	x																	
OUI-SS-SB314-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB315-0-1	Soil	SB-315	0-1 ft BLS	x	x	x	x	x	x												
OUI-SS-SB315-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB316-0-1	Soil	SB-316	0-1 ft BLS	x										x							
OUI-SS-SB316-2-4	Soil		2-4 ft BLS	x	x	x	x	x	x												
OUI-SS-SB317-0-1	Soil	SB-317	0-1 ft BLS	x																	
OUI-SS-SB317-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB318-0-1	Soil	SB-318	0-1 ft BLS	x																	
OUI-SS-SB318-2-4	Soil		2-4 ft BLS	x																	
OUI-SS-SB319-0-1	Soil	SB-319	0-1 ft BLS	x	x	x	x	x	x					x	x						
OUI-SS-SB319-2-4	Soil		2-4 ft BLS	x																	
OUI-SE-LVR201-yyymmdd	Sediment	LVR-201	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR201-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR202-yyymmdd	Sediment	LVR-202	0-6" Into Sediment	x																	
OUI-SW-LVR202-yyymmdd	Surface Water		Middle of Column	x																	
OUI-SE-LVR203-yyymmdd	Sediment	LVR-203	0-6" Into Sediment	x																	
OUI-SW-LVR203-yyymmdd	Surface Water		Middle of Column	x																	
OUI-SE-LVR204-yyymmdd	Sediment	LVR-204	0-6" Into Sediment	x																	
OUI-SW-LVR204-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR205-yyymmdd	Sediment	LVR-205	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR205-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR206-yyymmdd	Sediment	LVR-206	0-6" Into Sediment	x			x														

Table 1. Sampling Information for Solid, Air, Surface-Water, Sediment, and Groundwater Sampling
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Sample ID	Matrix	Location	Depth or Stratum	TAL Metals	VOCs	SVOCs	Pesticides	PCBs	Cyanide	Asbestos	TAL Metals SPLP	Soil pH	SEP	XRD	AVS/SEM	TOC	Orthophosphate	Sulfate	Field Parameters		
																			Ferrous Iron	Sulfide	Alkalinity
OUI-SE-LVR207-yyymmdd	Sediment	LVR-207	0-6" Into Sediment	x			x								x						
OUI-SW-LVR207-yyymmdd	Surface Water		Middle of Column	x			x														
OUI-SE-LVR208-yyymmdd	Sediment	LVR-208	0-6" Into Sediment	x			x														
OUI-SE-LVR209-yyymmdd	Sediment	LVR-209	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR209-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR210-yyymmdd	Sediment	LVR-210	0-6" Into Sediment	x																	
OUI-SE-LVR211-yyymmdd	Sediment	LVR-211	0-6" Into Sediment	x																	
OUI-SW-LVR211-yyymmdd	Surface Water		Middle of Column	x																	
OUI-SE-LVR212-yyymmdd	Sediment	LVR-212	0-6" Into Sediment	x																	
OUI-SE-LVR213-yyymmdd	Sediment	LVR-213	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR213-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-LVR214-yyymmdd	Sediment	LVR-214	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-LVR214-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-SE-UL215-yyymmdd	Sediment	UL-215	0-6" Into Sediment	x	x	x	x	x	x												
OUI-SW-UL215-yyymmdd	Surface Water		Middle of Column	x	x	x	x	x	x												
OUI-GW-MW-2-yyymm	Groundwater	MW-2	Alluvium	x	x	x			x							x	x	x	x	x	x
OUI-GW-MW-301H-yyymm	Groundwater	MW-301H	Alluvium	x															x	x	x
OUI-GW-MW-303H-yyymm	Groundwater	MW-303H	Alluvium	x															x	x	x
OUI-GW-MW-305H-yyymm	Groundwater	MW-305H	Alluvium	x															x	x	x
OUI-GW-MW-310H-yyymm	Groundwater	MW-310H	Alluvium	x	x	x			x							x	x	x	x	x	x
OUI-GW-P-17-yyymm	Groundwater	P-17	Alluvium	x															x	x	x
OUI-GW-P-18-yyymm	Groundwater	P-18	Alluvium	x															x	x	x
OUI-GW-G-02-yyymm	Groundwater	G-02	Bedrock	x												x	x	x	x	x	x
OUI-GW-G-101-yyymm	Groundwater	G-101	Bedrock	x	x	x			x										x	x	x
OUI-GW-MW-305R-yyymm	Groundwater	MW-305R	Bedrock	x															x	x	x
OUI-GW-MW-311R-yyymm	Groundwater	MW-311R	Bedrock	x												x	x	x	x	x	x
OUI-GW-MW-317R-yyymm	Groundwater	MW-317R	Bedrock	x												x	x	x	x	x	x
OUI-GW-P-15-yyymm	Groundwater	P-15	Bedrock	x	x	x			x										x	x	x
OUI-GW-P-7-yyymm	Groundwater	P-7	Bedrock	x															x	x	x
OUI-GW-P-9-yyymm	Groundwater	P-9	Bedrock	x												x	x	x	x	x	x
OUI-GW-G-05-yyymm	Groundwater	G-05	Fill	x												x	x	x	x	x	x
OUI-GW-P-20-yyymm	Groundwater	P-20	Fill	x	x	x			x							x	x	x	x	x	x
OUI-GW-G-106-yyymm	Groundwater	G-106	Slag	x												x	x	x	x	x	x
OUI-GW-MW-1-yyymm	Groundwater	MW-1	Slag	x															x	x	x
OUI-GW-MW-301S-yyymm	Groundwater	MW-301S	Slag	x															x	x	x
OUI-GW-MW-303S-yyymm	Groundwater	MW-303S	Slag	x	x	x			x										x	x	x
OUI-GW-MW-304S-yyymm	Groundwater	MW-304S	Slag	x															x	x	x
OUI-GW-MW-305S-yyymm	Groundwater	MW-305S	Slag	x												x	x	x	x	x	x
OUI-GW-MW-306S-yyymm	Groundwater	MW-306S	Slag	x															x	x	x
OUI-GW-P-1-yyymm	Groundwater	P-1	Slag	x	x	x			x										x	x	x
OUI-GW-P-15A-yyymm	Groundwater	P-15A	Slag	x															x	x	x
OUI-GW-P-19-yyymm	Groundwater	P-19	Slag	x															x	x	x
OUI-GW-G-04-yyymm	Groundwater	G-04	Till	x												x	x	x	x	x	x
OUI-GW-G-103-yyymm	Groundwater	G-103	Till	x	x	x			x										x	x	x
OUI-GW-P-6-yyymm	Groundwater	P-6	Till	x												x	x	x	x	x	x

- Notes:
1. ID: Identification
 2. TAL: Target Analyte List
 3. VOC: Volatile Organic Compound
 4. SVOC: Semi-Volatile Organic Compound
 5. PCB: Polychlorinated Biphenyl
 6. SPLP: Synthetic Precipitation Leaching Procedure
 7. SEP: Sequential Extraction Procedure
 8. XRD: X-Ray Diffraction
 9. AVS/SEM: Acid Volatile Sulfide/Simultaneously Extracted Metals
 10. TOC: Total Organic Carbon
 11. TBD: To Be Determined
 12. ft BLS: feet below land surface
 13. OUI: Operable Unit 1
 14. SW: Surface Water
 15. SE: Sediment
 16. SS: Solid Matrix
 17. SB: Soil Boring
 18. LVR: Little Vermilion River
 19. UL: Upland
 20. Where "Slag/Soil" is indicated in matrix column, the actual matrix encountered will be noted during sampling.

Table 2. Summary of Container, Preservation, and Hold Requirements for Samples
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Matrix	Parameter (Analysis)	Sample Container	Preservation	Holding Time
Solid (Soil, Sediment, Slag)	TAL Metals (EPA Methods 6010B/6020/7471A)	1-8 oz WM Jar	Cool to 4° C	6 Months; Mercury 28 Days
	TAL Metals SPLP Extraction (EPA Method 1312)	1-8 oz WM Jar	Cool to 4° C	180 Days from Collection to Extraction 180 Days from Extraction to Analysis (28 Days for Mercury)
	Cyanide (EPA Method 9012A)	1-8 oz WM Jar	Cool to 4° C	14 Days
	VOCs (EPA Method 8260B)	3-40 mL WM Glass vials	Cool to 4° C Methanol/Sodium Disulfate	14 Days
	SVOCs (EPA Method 8270C)	1-8 oz WM Amber Glass Jar	Cool to 4° C	14 Days to Extraction; 40 Days after Extraction
	Pesticides/PCBs (EPA Method 8081A/EPA Method 8082)	1-8 oz WM Amber Glass Jar	Cool to 4° C	14 Days to Extraction; 40 Days after Extraction
	Cu, Cd, Ni, Zn, Pb (AVS/SEM)	1-4 oz WM Amber Glass Jar	Cool to 4° C; No Headspace	14 Days
	Soil Minerals XRD (MSD 0700)	1-8 oz WM Jar	None	None
	Soil pH (EPA Method 9045D)	1-4 oz WM Glass Jar	Cool to 4° C; No Headspace	None, ASAP preferred (24 Hours)
	Trace Metals SEP (Laboratory specific SOP)	1-250-mL WM Clear Glass Jar	Cool to 4° C	180 Days (28 Days for Mercury)
Aqueous	VOCs (EPA Method 8260B)	3-40 mL Glass	Cool to 4° C 1:1 HCl to pH < 2	14 Days
	SVOCs (EPA Method 8270C)	2-1L Amber	Cool to 4° C	7 Days to Extraction; 40 Days to Analysis
	Pesticides/PCBs (EPA Method 8081A/EPA Method 8082)	2-1L Amber for Each Method	Cool to 4° C Sodium Thiosulfate Preservative	7 Days to Extraction; 40 Days to Analysis
	TAL Metals (EPA Methods 6010B/6020/7471A)	1-1L Plastic (Filtered) 1-1L Plastic (Unfiltered)	Cool to 4° C; HNO ₃ to pH < 2	180 Days; Mercury 28 Days
	Cyanide (EPA Method 9012A)	1-1L Plastic	NaOH to pH > 12 Cool to 4° C	14 Days
	Total Organic Carbon (EPA Method 9060)	1-250 mL Plastic	Cool to 4° C	28 Days
	Orthophosphate (EPA Method 300.0-9056)	1-250 mL Plastic	Cool to 4° C	28 Days
	Sulfate (EPA Method 300.0-9056)	1-250 mL Plastic	Cool to 4° C	48 Hours
Ambient Air	Asbestos (NIOSH 7100)	NIOSH 7400 Cassette (25mm dia., 0.8µm effective pore size)	Double Bag	None
	Arsenic, Lead (ICP for PM10 Samples - Method 6010B)	8x10" quartz microfiber filters	None	6 months
Liquid Investigation- Derived Waste	TCLP VOCs (SW846 8260B)	2-40 mL Glass	Cool to 4° C 1:1 HCl to pH < 2	14 Days
	TCLP SVOCs (SW846 8270)	2-1L Glass	Cool to 4° C	7 Days to Extraction 40 Days to Analysis
	TCLP Pesticides/Herbicides (SW846 8081/SW846 8151)	2-1L Glass	Cool to 4° C	7 Days to Extraction 40 Days to Analysis
	TCLP Metals, except Hg (SW846)	1-500 mL Plastic	Cool to 4° C HNO ₃ to pH < 2	180 Days
	TCLP Mercury (EPA Method 245.1/7470/7471)	1-500 mL Plastic	Cool to 4° C HNO ₃ to pH < 2	28 Days
Solid Investigation- Derived Waste	TCLP VOCs (SW846 8260B)	1-4 oz. Glass	Cool to 4° C	14 Days to TCLP Extraction + 14 Days to Analysis (28 Total)
	TCLP SVOCs (SW846 8270)	1-4 oz. Glass	Cool to 4° C	14 Days to TCLP Extraction + 7 Days to Sample Extraction + 40 Days to Analysis (61 Total)
	TCLP Pesticides/Herbicides (SW846 8081/SW846 8151)	1-4 oz. Glass	Cool to 4° C	14 Days to TCLP Extraction + 7 Days to Sample Extraction + 40 Days to Analysis (61 Total)
	TCLP Metals, except Hg (SW846)	1-4 oz. Glass	Cool to 4° C	180 Days to TCLP Extraction + 180 Days to Analysis (360 Total)
	TCLP Mercury (EPA Method 245.1/7470/7471)	1-4 oz. Glass	Cool to 4° C	28 Days to TCLP Extraction + 28 Days to Analysis (16 Total)

Notes:

- | | | |
|---|---|-----------------------------------|
| 1. C: Centigrade | 9. EPA: United States Environmental Protection Agency | 17. PCB: Polychlorinated Biphenyl |
| 2. WM: Wide-Mouth | 10. SOP: Standard Operating Procedure | 18. mL: milliliter |
| 3. TAL: Target Analyte List | 11. VOC: Volatile Organic Compound | 19. L: liter |
| 4. XRD: X-Ray Diffraction Analysis | 12. SVOC: Semi-Volatile Organic Compound | 20. oz.: ounce |
| 5. SPLP: Synthetic Precipitation Leaching Procedure | 13. Cu, Cd, Ni, Zn, Pb: copper, cadmium, nickel, zinc, lead | |
| 6. SEP: Sequential Extraction Procedure | 14. Hg: mercury | |
| 7. AVS: Acid Volatile Sulfide | 15. TCLP: Toxicity Characteristic Leaching Procedure | |
| 8. SEM: Simultaneously Extracted Metals | 16. ICP: Inductively Coupled Plasma | |

Table 3. Inventory of Existing Monitoring Wells and Piezometers
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Well/Piezometer	Top Casing Elevation	Bottom of Screen Depth (ft BLS)	Top of Screen Depth (ft BLS)	Stickup Height	Installation Date	Geologic Horizon
G-02	568.39	22	12	2.7	NA	Shale and Coal
G-04	575.3	19	9	2.67	NA	Coarse Till
G-05	577.47	24	12	2.58	NA	Soil Fill
G-101	575.95	23	13	2.27	NA	Shale
G-103	574.57	22.03	12.03	1.87	NA	Fine Till
G-106	573.23	30.33	15.33	1.71	NA	Slag
MW-1	572.27	24.69	14.69	2.48	NA	Slag
MW-2	489.08	58.25	0	0	NA	Alluvium
P-1	548.81	88	78	1.86	10/3/1994	Red & Gray Slag
P-15	491.78	40	35	2.57	9/28/1994	Green Shale
P-15A	492.02	25	20	2.8	9/29/1994	Red & Gray Slag
P-17	490.4	48	38	2.69	9/30/1994	Alluvium Below Slag
P-18	508.49	60	50	2.64	9/28/1994	Alluvium Below Slag
P-19	514.54	53	43	2.64	9/29/1994	Black Slag
P-20	545.97	21	11	2.78	9/29/1994	Black Granular Fill
P-6	573.95	24	9	2.64	10/11/1994	Silty Clay/Fine Till
P-7	545.21	20	10	2.66	9/28/1994	Shale
P-9	534.53	10	5	2.67	9/27/1994	Shale

Notes:

1. NA: Information not available.
2. All units are ft.
3. ft BLS: feet below land surface

Table 4. Action Levels for Metal Chemicals of Potential Concern in Ambient Air Samples
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois

Parameter	Chemical Abstract Service (CAS) Number	Method	OSHA PEL-TWA (mg/m ³)	ACGIH PEL-TWA (mg/m ³)	Project Action Limits ¹ (mg/m ³)
Metals					
Arsenic	7440-38-2	6010B (ICP for PM10)	0.01	0.01	0.005
Lead	7439-92-1	6010B (ICP for PM10)	0.05	0.05	0.025

Notes:

1. Project Action Limits are one half of lower of Occupational Safety and Health Administration (OSHA) and American Conference of Governmental Industrial Hygienists (ACGIH) standards.

2. mg/m³: Milligrams per cubic meter.

**Table 5. Field Quality Control Samples
Remedial Investigation/Feasibility Study
Matthiessen and Hegeler Zinc Company Site, Operable Unit 1
LaSalle, Illinois**

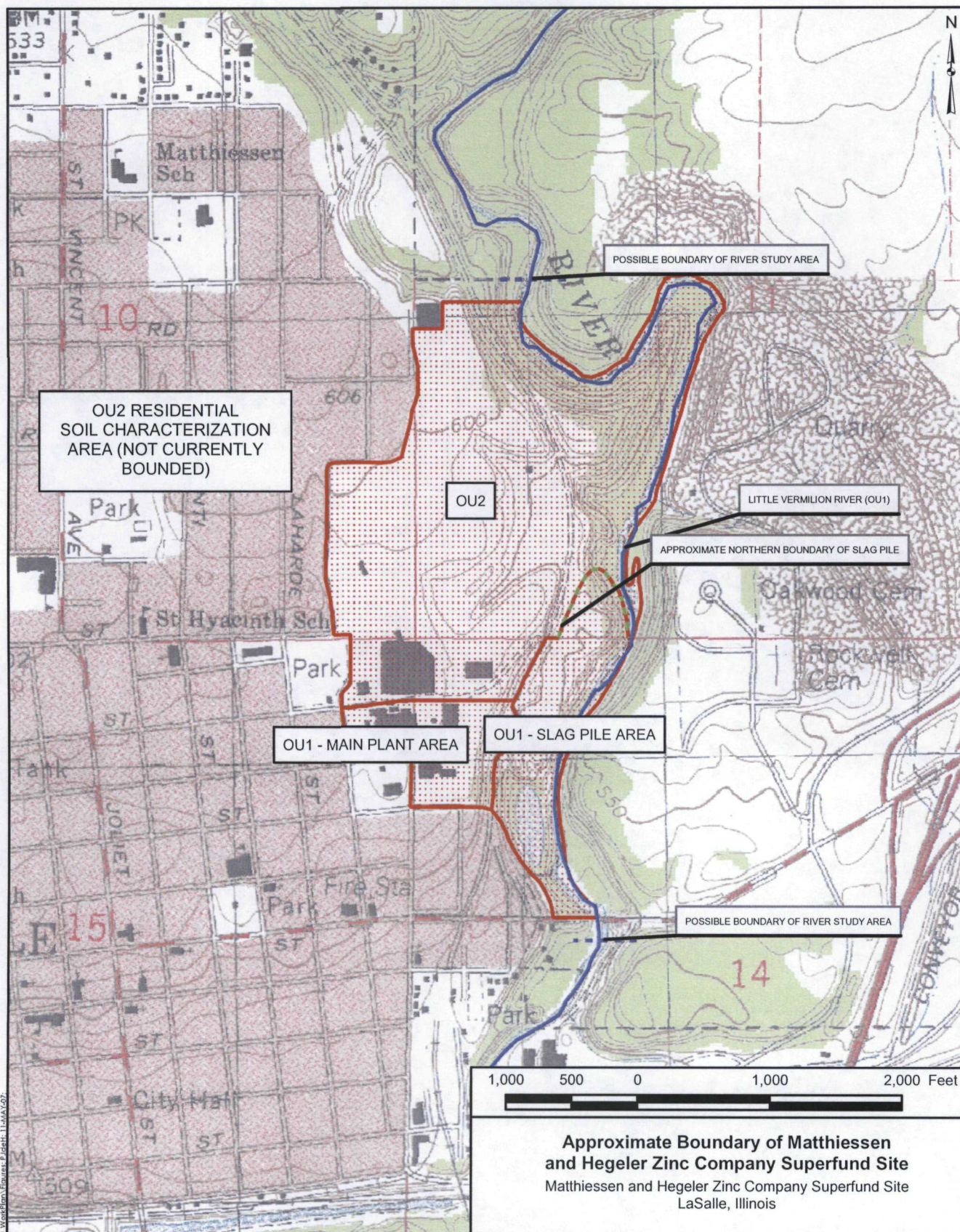
Parameter	Matrix	Trip Blanks	MS/MSD ⁽¹⁾	Equipment Rinsate Blanks ⁽²⁾	Filter Blank	Field Blank	Duplicate Samples
VOC's	Water	1 per cooler of VOC samples	1 set 20 samples	1 per 20 samples or 1 per day	NA	1 per source or 1 per day	1 per 20 samples
SVOC's		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
TAL Metals		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	1 per source or 1 per day	1 per 20 samples
Pesticides PCBs		NA	1 set 20 samples	1 per 20 samples or 1 per day	1 set 20 samples	NA	1 per 20 samples
Cyanide		NA	1 set 10 samples	1 per 20 samples or 1 per day	NA	NA	1 per 10 samples
Sulfate		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
Orthophosphate		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
Total Organic Carbon		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
TAL Metals	Soil Sediment	NA	1 set 20 samples (double volume only)	1 per 20 samples or 1 per day	NA	1 per source or 1 per day	1 per 20 samples
TAL Metals SPLP		NA	1 set 20 samples (double volume only)	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
Cyanide		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 10 samples
VOC's		1 per cooler of VOC samples	1 set 20 samples	1 per 20 samples or 1 per day	NA	1 per source or 1 per day	1 per 20 samples
SVOC's		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
Cu, Cd, Ni, Zn, Pb (AVS SEM)		NA	NA	NA	NA	NA	1 per 20 samples
Soil Minerals (XRD)		NA	NA	NA	NA	NA	1 per 20 samples
Trace Metals SEP		NA	NA	NA	NA	NA	1 per 20 samples
Soil pH		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
Pesticides PCBs		NA	1 set 20 samples	1 per 20 samples or 1 per day	NA	NA	1 per 20 samples
Arsenic, Lead, Asbestos	Ambient Air	NA	NA	NA	NA	NA	1 per 20 samples

Notes:

1. Field personnel must collect triple volume to account for MS MSD sample.
2. No equipment blanks are required for disposable or dedicated field sampling equipment.
3. NA: Not Applicable
4. VOC: Volatile Organic Compound
5. SVOC: Semi-Volatile Organic Compound
6. TAL: Target Analyte List
7. PCB: Polychlorinated Biphenyl
8. SPLP: Synthetic Precipitation Leaching Procedure

9. Cu, Cd, Ni, Zn, Pb: copper, cadmium, nickel, zinc, lead
10. AVS: Acid Volatile Sulfide
11. SEM: Simultaneously Extracted Metals
12. XRD: X-Ray Diffraction Analysis
13. SEP: Sequential Extraction Procedure
14. MS MSD: Matrix Spike Matrix Spike Duplicate

FIGURES



Note:

Basemap Source:
USGS 7.5 min Series, LaSalle Quadrangle

Geosyntec
consultants

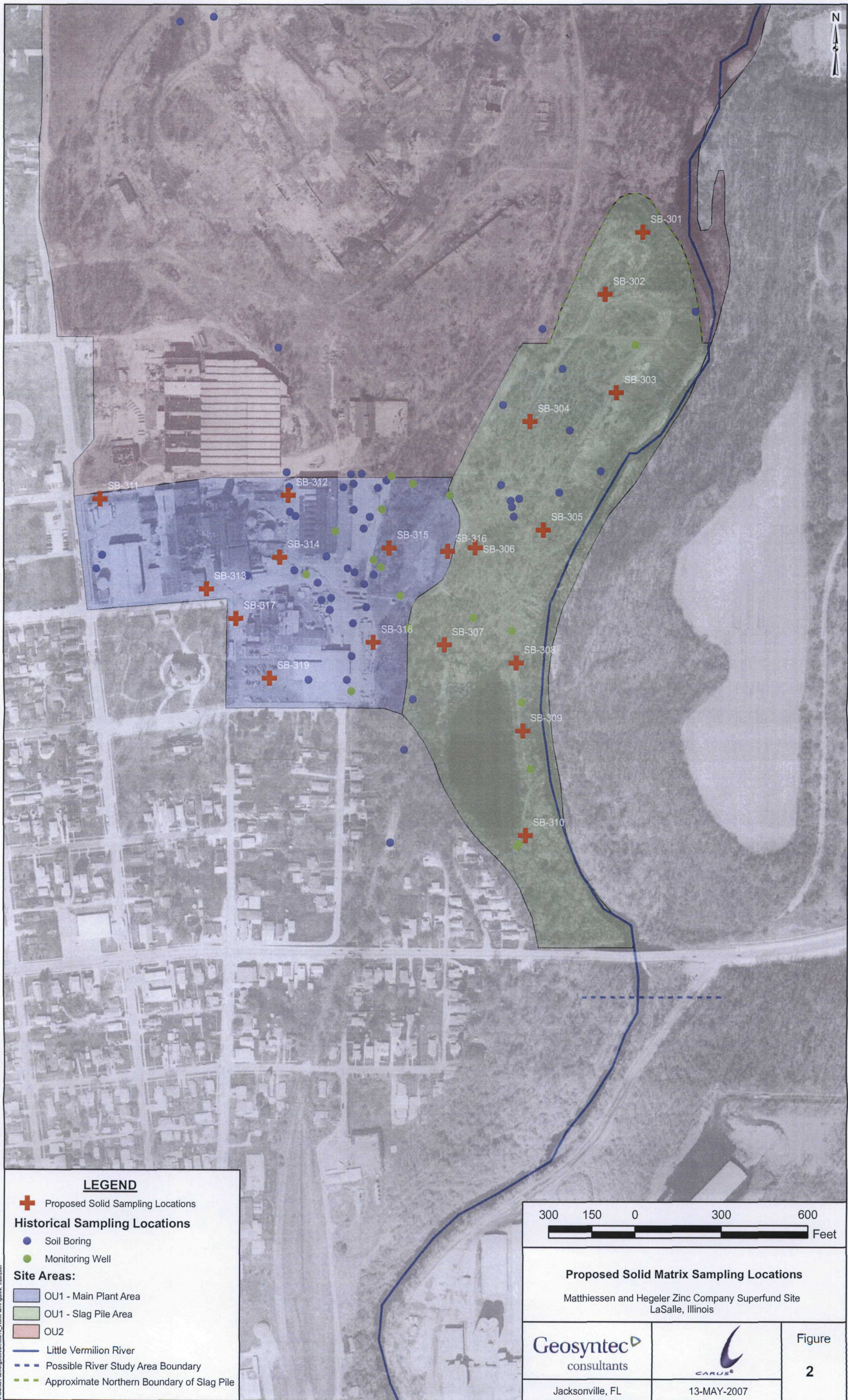
Jacksonville, FL



11-MAY-07

Figure

1



LEGEND

+ Proposed Solid Sampling Locations

Historical Sampling Locations

• Soil Boring

• Monitoring Well

Site Areas:

■ OU1 - Main Plant Area

■ OU1 - Slag Pile Area

■ OU2

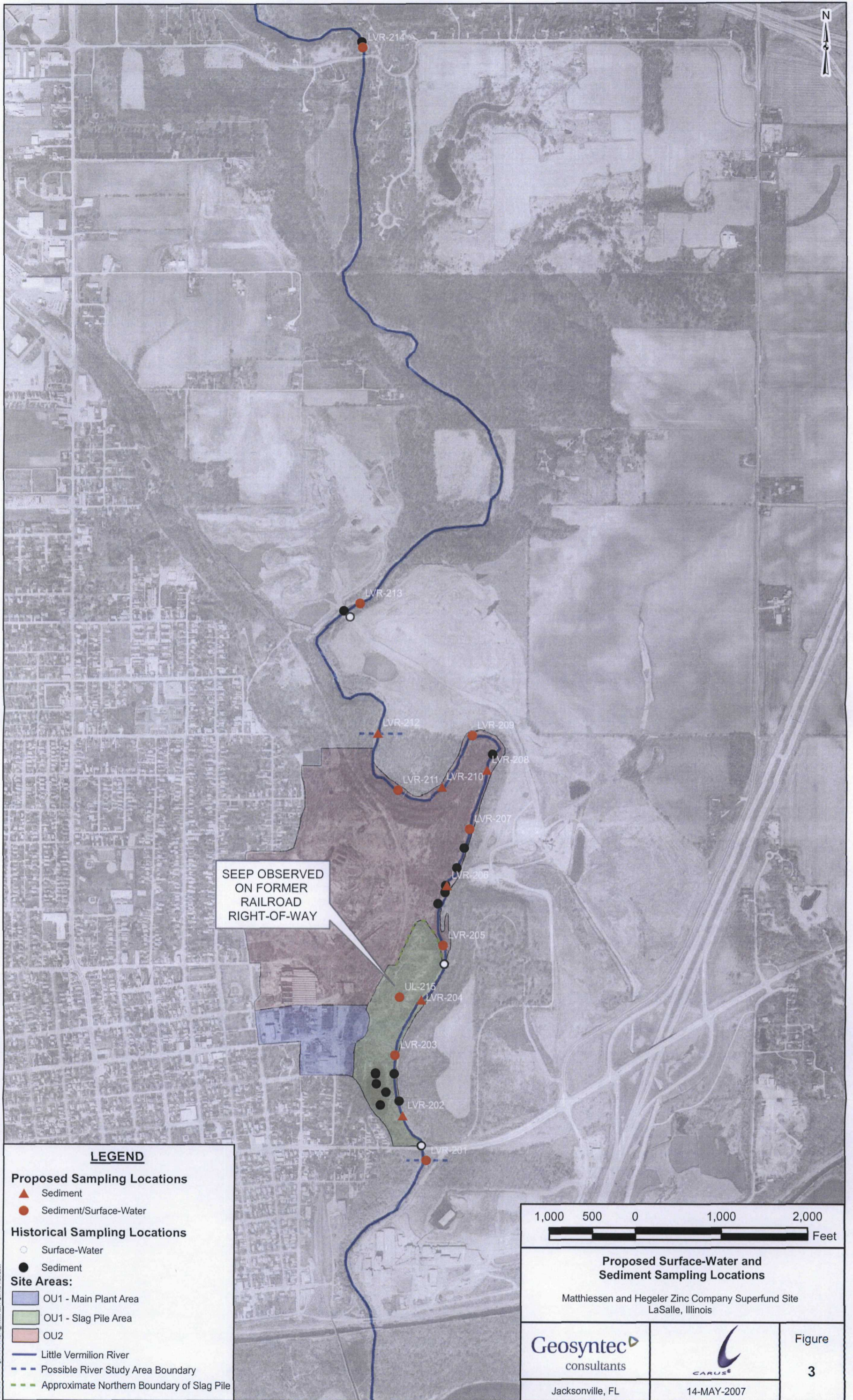
— Little Vermilion River

- - - Possible River Study Area Boundary

- - - Approximate Northern Boundary of Slag Pile

<p>300 150 0 300 600</p> <p>Feet</p>		
<p>Proposed Solid Matrix Sampling Locations</p> <p>Matthiessen and Hegeler Zinc Company Superfund Site LaSalle, Illinois</p>		
<p>Geosyntec consultants</p>		<p>Figure 2</p>
<p>Jacksonville, FL</p>	<p>13-MAY-2007</p>	

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SUBMITTAL OF THE FINAL
QAPP IS CONTINGENT UPON
RECEIPT OF COMMENTS
FROM THE USEPA

Prepared for:



**Carus Corporation and
Carus Chemical Company**

1500 Eighth Street
P.O. Box 1500
LaSalle, Illinois 61301-3500

HEALTH AND SAFETY PLAN REVISION 1

REMEDIAL INVESTIGATION/FEASIBILITY STUDY

**MATTHIESSEN AND HEGELER ZINC COMPANY SITE
LASALLE, ILLINOIS**

Prepared by:

Geosyntec 
consultants

engineers | scientists | innovators

2258 Riverside Avenue
Jacksonville, Florida 32204

Geosyntec Consultants Project Number FR1093

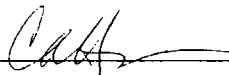
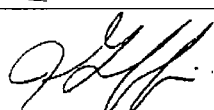
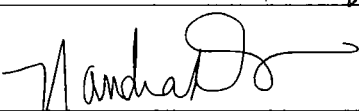
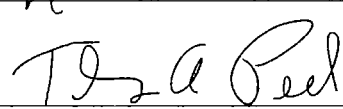
May 2007

Project Health and Safety Plan (HASP)

Project Name: Matthiessen and Hegeler Zinc Company Site in
LaSalle, Illinois

Project Number: FR1093 (Carus)

This HASP, which must be kept on site, addresses the safety and health hazards of each phase of site operation, including the requirements and procedures for worker protection. Only the Site Health and Safety Officer (SHSO) can change or amend this document in agreement with the Environmental Health and Safety Coordinator (EHSC), Project Manager, and Principal-in-Charge. The SHSO must initial any change made to the HASP at the relevant section. Major amendments (e.g., changes in personal protective equipment not provided for in this plan, addition of tasks, etc.) must be documented by indicating the amendment date shown on this page.

Prepared by:	Catherine Hajcak HSO		05/12/07 Date
Reviewed by:	James Griffin EHSC		05/12/07 Date
Approved by:	Nandra Weeks Project Manager		05/12/07 Date
	Tom Peel Principal-in-Charge / Associate-in-Charge		05/12/07 Date

Copy Cover Sheet to: EHSC

Brief Description of Amendment

Amendment Date

This HASP has been given to the following subcontractor(s) in accordance with OSHA 29 CFR 1910.1200 (Hazard Communication Standard):

Subcontractor: _____ Representative: _____ Date: _____

Subcontractor: _____ Representative: _____ Date: _____

Geosyntec site workers must read this HASP. A pre-entry briefing conducted by the SHSO must be held prior to initiating this project. All sections of this HASP must be reviewed during this briefing. Any worker not in attendance at the initial meeting must be trained by the SHSO on the information covered in the pre-entry briefing meeting. ***Tailgate meetings must be held at the beginning of the work shift by the SHSO to discuss important safety and health issues concerning tasks performed on that day. A brief description of topics discussed in tailgate meetings must be documented in the Field log book.*** After reading the HASP and attending a pre-entry briefing, workers must sign the following acknowledgment statement.

I have read, understand, and agree with the information set forth in this HASP. I have also attended a pre-entry briefing. I agree to perform my work in accordance with this HASP.

Name	Date	Name	Date
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

TABLE OF CONTENTS

1.	SITE/TASK DESCRIPTION	1
2.	KEY PERSONNEL AND HEALTH AND SAFETY RESPONSIBILITIES	2
3.	WORKER TRAINING	3
4.	SITE CONTROL	3
	4.1 Site Map	3
	4.2 Buddy System	3
	4.3 Work Zones.....	3
	4.4 Site Access	4
	4.5 Visitors	4
	4.6 Communications	4
	4.7 Safe Work Practices	4
	4.8 Inspections	5
5.	HAZARD ANALYSIS AND MITIGATORS	5
	5.1 Chemical Hazards	5
	5.2 Physical Hazards	6
	5.3 Biological Hazards	6
6.	AIR MONITORING	6
	6.1 Real-Time Air Monitoring.....	6
	6.2 Personal/Area Air Monitoring	7
7.	MEDICAL SURVEILLANCE.....	7
8.	PERSONAL PROTECTIVE EQUIPMENT.....	7
9.	DECONTAMINATION	8
10.	EMERGENCY PREPAREDNESS AND RESPONSE.....	8
11.	CONFINED SPACE ENTRY.....	9
12.	SPILL CONTAINMENT	9
13.	HAZARD COMMUNICATION	9

TABLE OF CONTENTS (continued)

LIST OF FIGURES

Figure 1	Site Map
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LIST OF TABLES

Table 1	Key Personnel and Health & Safety Responsibilities
Table 2	Training / Medical Surveillance / Respirator Fit Test Records
Table 3	General Safe Work Practices
Table 4	Contaminants of Concern
Table 5	Hazard Analysis
Table 6	Emergency Response Contacts
Table 7	Emergency Response Procedures

ATTACHMENTS

Attachment A	Weekly Health & Safety Inspection Checklist
Attachment B	Contaminant Fact Sheet Directory
Attachment C	Hazard Mitigators
Attachment D	Air Monitoring Equipment/Frequency of Reading/Action Guidelines Per Task
Attachment E	Personal Protective Equipment Per Task
Attachment F	Decontamination Procedures and Equipment
Attachment G	Material Safety Data Sheets

1. SITE/TASK DESCRIPTION

Brief description of site (including information as to current and previous site usage, location and approximate size of site, and a description of the tasks):

- Site Usage: Carus manufacturing facility; former smelter and waste disposal operations
- Site Location: 1500 Eighth Street, NW quarter Section 14 & NE quarter Section 15, Township 33 North, Range 1 East, of the Third Principal Meridian in LaSalle, Illinois
- Size of Site: approximately 47 acres
- Expected Field Dates: 1 April 2007 – 31 March 2008
(Beginning date - ending date)
- Tasks for this project include:

① Slag waste material and soil sampling – Solid Matrix Characterization Program

② Boring installation (hand auger and drill rig) – Solid Matrix Characterization Program

③ Trenching – Solid Matrix Characterization Program

④ Sediment and surface water sampling – River Characterization Program

⑤ Well boring and installation – Groundwater Characterization Program

⑥ Groundwater sampling – Groundwater Characterization Program

⑦

⑧

- Description of Surrounding Property/Population:

North	Limestone quarry and cemetery	East	Little Vermilion River and farmland
-------	-------------------------------	------	-------------------------------------

South	Private residences	West	Private residences
-------	--------------------	------	--------------------

- Site Condition and Topography:

OU1 is comprised of three areas: (i) Carus' manufacturing facility; (ii) a slag pile related to the former Matthiessen and Hegeler (M&H) smelter operations; and (iii) the Little Vermilion River. The Carus manufacturing facility is located at 1500 Eighth Street, in the northwest quarter of Section 14 and in the northeast quarter of Section 15 in Township 33 North, Range 1 East of the Third Principal Meridian in LaSalle County, Illinois. The slag pile is located in the northwest quarter of Section 14 in the township referenced above and is bordered to the east by the Little Vermilion River. The river generally runs from north to south toward its confluence with the Illinois River approximately one mile south of the Site; it also serves as the eastern boundary of Operable Unit 1 (OU1) and Operable Unit 2 (OU2). A location map is provided as Figure 1. Note that the northern boundary of the slag pile serves as part of the boundary between OU1 and OU2; this boundary is dashed on associated figures because the boundary is estimated at present. Likewise, the spatial extent of site-related impacts in the Little Vermilion River will be better understood during and after RI characterization; hence, dashed boundary lines immediately to the north and south of the site indicate possible study boundaries.

The main plant area of Carus contains numerous buildings associated with the manufacture of potassium permanganate and other specialty chemicals. Property to the east of the main plant area includes, from west to east: (i) the eastern embankment of the manufacturing facility; (ii) a segment of the former Illinois Central Railroad (ICRR) embankment; and (iii) the slag pile associated with the M&H Zinc Company Site. A holding pond and an emergency bypass pond associated with Carus' operations and its National Pollutant Discharge Elimination System (NPDES) permit (Number IL0002623) are located on or near the slag pile. OU1 is bounded by OU2 of the M&H Site to the north; a limestone quarry, a cemetery, and farmland to the east; and private residences to the south and west.

2. KEY PERSONNEL AND HEALTH AND SAFETY RESPONSIBILITIES

Table 1 lists project personnel and their responsibilities in regard to health and safety concerns on this project.

3. WORKER TRAINING

Table 2 documents that workers have received the appropriate training requirements according to the company Environmental, Health, and Safety (EH&S) Training Program. A pre-entry briefing and daily tailgate meetings are also conducted to facilitate onsite training.

4. SITE CONTROL

Site control procedures must be implemented **before** the start of site tasks to control worker exposures to hazardous substances.

4.1 Site Map

A site map is shown in Figure 1. The following items are included on the site map.

- General Wind Direction
- Evacuation Routes
- Refuge Locations
- Route to Nearest Hospital or Medical Assistance (may be provided on separate map)

Changes may be made to the site map by the SHSO, as needed, based on site conditions. The site map should be posted in the work area.

4.2 Buddy System

APPLIES TO TASK ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

The Buddy System is required in the task(s) indicated above. The buddy system includes maintaining regular contact (see Section 4.6) with onsite Geosyntec personnel, clients and/or contractors.

4.3. Work Zones

Three work zones must be established for each task. The Exclusion Zone is defined as the area on-site where contamination is suspected and tasks are to be performed. The Contamination Reduction Zone (CRZ) is defined as the area where equipment and workers are to be decontaminated. The Support Zone is defined as the command area and serves as a storage area for supplies. The exact location and extent of the work zones will be modified as necessary as site investigation information becomes available.

The boundaries of the Exclusion Zone, CRZ, and Support Zone must be marked using the following methods:

- | | |
|---|---|
| <input checked="" type="checkbox"/> Warning tape (high traffic areas) | <input checked="" type="checkbox"/> Traffic cones |
| <input type="checkbox"/> Signs | <input type="checkbox"/> Fence |
| <input type="checkbox"/> Other _____ | |

4.4. Site Access

Access to the site must be controlled using the following method:

- | | |
|---|---|
| <input type="checkbox"/> Sign in/Sign out log | <input type="checkbox"/> Guard |
| <input checked="" type="checkbox"/> Badges | <input checked="" type="checkbox"/> Other: <u>Site log book</u> |

4.5. Visitors

Visitors to the site must be continually escorted in order to assure their safety since they may be unfamiliar with the site. Visitors must not be allowed past the Support Zone unless they read, understand, sign, and meet the requirements outlined in this HASP.

4.6. Communications

On-site communications must be conducted through the use of:

- | | |
|--|---------------------------------------|
| <input checked="" type="checkbox"/> Verbal | |
| <input type="checkbox"/> Two-way radio | <input type="checkbox"/> Horn |
| <input checked="" type="checkbox"/> Cellular telephone | <input type="checkbox"/> Siren |
| <input checked="" type="checkbox"/> Hand signals | <input type="checkbox"/> Other: _____ |

Off-site communications must be conducted through the use of:

- | |
|--|
| <input checked="" type="checkbox"/> Cellular telephone |
| <input type="checkbox"/> Pay phone: Location _____ |
| <input type="checkbox"/> Other: _____ |

4.7. Safe Work Practices

General Safe Work Practices that must be implemented during work activities at this site are included in Table 3.

4.8. Inspections

For projects lasting longer than one week, the SHSO must conduct weekly health and safety inspections. The inspections must be documented using the Weekly Health & Safety Inspection checklist included in Attachment A. The Weekly Health & Safety Inspection Checklist must be kept on file at the project site.

5. HAZARD ANALYSIS AND MITIGATORS

Site specific hazards must be identified (through hazard analysis) to determine the appropriate safety and health hazard mitigators needed to protect workers from the identified hazards. Hazard analysis involves a complete review of chemical, physical, and biological hazards.

5.1 Chemical Hazards ☒ APPLICABLE ☐ NOT APPLICABLE

A comparison has been made between previous environmental sampling results and USEPA Region 9 Preliminary Remediation Goals (PRGs)) (for tapwater and industrial soils) to select those contaminants that may cause health and safety concerns, henceforth referred to as Contaminants of Concern (COCs). Based on this comparison, only contaminants that exceed five times these standards have been considered COCs as indicated in Table 4. This protocol of selecting COCs (i.e., those with concentrations of at least five times the above referenced standards) has been designed to be protective of site worker health and safety. The referenced standards are not intended as cleanup goals; they are screening values to be used to select chemicals to be included in a risk assessment, and therefore, are considered to be very conservative. The industrial soil PRGs are calculated to be protective of site workers over a 25-year period. For carcinogenic COCs, risk levels are proportional to exposure duration. Hence, elevating industrial soil PRGs by a factor of five entails an assumption that a given field personnel for the RI/FS will not work more than five years on-site at 250 days per year. For non-carcinogenic COCs, the time proportionality conversion cannot be made; however, one can generally convert risk-based criteria based on chronic exposures (which are the source of PRGs) to those based on subchronic exposures, which correspond to exposures for 10% of one's life, or seven years. Again, seven years is a conservatively high assumption for RI/FS fieldwork duration for a given field staff personnel. Typically, the conversions from chronic to subchronic reference dose or concentrations entail a tenfold increase; hence, the fivefold increase assumed herein is conservative. Similar explanations can be made for tapwater PRGs.

Contaminant Fact Sheets for each of the Contaminants of Concern for this project are provided in Attachment B.

Information from the Contaminant Fact Sheets (e.g., flash point, water reactive, etc.) have been utilized in performing the chemical hazard analysis in Table 5 (e.g., fire, inhalation, reactivity, and skin absorption hazards). If, based on the hazard analysis, chemical hazards exist, hazard mitigators must be utilized to control these hazards (Attachment C). In addition, air monitoring equipment (Section 6) and personal protective equipment (PPE) (Section 8) must also be utilized to evaluate airborne concentrations and protect workers.

5.2 Physical Hazards ☒ APPLICABLE ☐ NOT APPLICABLE

Physical hazards associated with tasks to be performed (e.g., electrocution due to drilling, etc.) and site location (e.g., slips, trip, or falls due to rocky terrain, etc.) have been analyzed in Table 5. If, based on the hazard analysis, physical hazards exist, hazard mitigators (Attachment C) must be implemented.

5.3 Biological Hazards ☒ APPLICABLE ☐ NOT APPLICABLE

If, based on the hazard analysis (Table 5), biological hazards exist associated with tasks to be performed and site location (e.g., allergic reactions to poisonous plants or insects indigenous to the area, etc.), hazard mitigators (Attachment C) must be implemented.

6. AIR MONITORING

6.1 Real-Time Air Monitoring ☒ APPLICABLE ☐ NOT APPLICABLE

The types of air monitoring equipment required, initial frequency of readings, and action guidelines for each task are provided in Attachment D. Action guidelines for contaminant vapor(s) and particulate matter are based on the hazard analysis (Section 6) and an analysis of any previous sampling results. Consideration is also given to vapor density and carcinogenicity where applicable.

Frequency of air monitoring readings will be adjusted on site accordingly, with the consent of the SHSO. Equipment must be calibrated at least before work begins each day and at the end of the day. Air monitoring readings and calibration records must be documented in the field log book.

6.2 Personal/Area Air Monitoring ☒ APPLICABLE ☐ NOT APPLICABLE

Personal/area air monitoring is required for the following contaminants of concern:

Monitor dust particulate when trenching, hand augering, and drilling. Decision will be made in the field, after initial monitoring, if continual monitoring will be required. Air sampling will be performed for arsenic and lead only during the intrusive sampling program associated with the slag pile. Sampling will be performed in two locations on each of the first two days of intrusive operations. PPE downgrade from Level C to Level D will not occur until favorable air monitoring data have been received as described in the FSP. Sampling is described in greater detail in Section 2.5 of the FSP.

7. MEDICAL SURVEILLANCE

Table 2 indicates the workers who participate in the company Medical Surveillance Program.

☒ Yes ☐ No Additional project-specific medical surveillance is required for the following contaminants of concern:

arsenic and lead

8. PERSONAL PROTECTIVE EQUIPMENT

☒ APPLICABLE ☐ NOT APPLICABLE

The levels of personal protection required for each task are provided in Attachment E. Required equipment and types of protective clothing materials are listed, as well as an indication of the initial level of protection. PPE levels must be indicated in the field log book. The level of protection may be upgraded or downgraded (by the SHSO) based on the action guidelines provided in Attachment D. As shown in Attachment D, continuous air monitoring will be conducted with a PID for volatile organics and a high-volume sampler with quartz filter and/or Gilian Air Sample Pump Kit with filter cassette for arsenic and lead during invasive field activities under tasks 1, 2, 3, and 5. For field activities conducted under these tasks related to slag material, field personnel will begin in Level C and downgrade to Level D, as possible, when favorable air monitoring results are measured according to the breathing zone levels outlined in

Attachment D. For field activities conducted under tasks 1, 2, 3, and 5 not related to slag material, field personnel will begin in Level D and upgrade to Level C, if necessary, according to the breathing zone levels outlined in Attachment D. Field personnel will don Level D PPE for field activities conducted under tasks 4 and 6. If metals concentrations are below one half of the most stringent occupational standard, then PPE will be downgraded to Level D protection for the remainder of the RI/FS. If concentration levels are greater than one half of the most stringent standard, then intrusive operations will continue in Level C protection.

If respirators are worn, workers must adhere to the company's Respiratory Protection Program (29 CFR §1910.134). Table 2 provides a record of the site workers' last annual fit test. Beards (i.e., facial hair interfering with the respirator seal) are not allowed.

9. DECONTAMINATION ☒ APPLICABLE ☐ NOT APPLICABLE

PPE must be decontaminated as per 29 CFR §1910.120(k). The decontamination procedures, equipment and decontamination solution required for each task are provided in Attachment F. In an emergency, the primary concern is to prevent the loss of life or severe injury to site personnel. If immediate medical treatment is required to save a life, decontamination should be delayed until the victim is stabilized. If decontamination can be performed without interfering with essential life-saving measures or first aid, or if worker has been contaminated with an extremely toxic or corrosive material that could cause severe injury or loss of life, decontamination must be performed in coordination with or prior to initial medical treatment at the scene.

10. EMERGENCY PREPAREDNESS AND RESPONSE

A list of contacts and telephone numbers for the applicable local off-site emergency responders is provided in Table 6. The nature of the site work and contaminants of concern should be reviewed with the off-site responders before work begins on this project. The following emergency response equipment is required for this project:

- ☐ Fire Extinguisher: ☐ Type A ☐ Type B ☐ Type C ☐
Type ABC
- ☐ Eyewash (Note: 15 minutes of free-flowing fresh water)
- ☐ SCBA
- ☒ First Aid Kit

☐ Shower (Note: for acids and caustics)

☐ Other: _____

The emergency response communication system for the site is:

☒ Verbal

☐ Two-way radio

☒ Hand signals: Hand gripping throat = "Out of Air, Can't Breathe"
Grip partner's wrist or both hands around waist = "Leave area immediately"
Hands on top of head = "Need assistance"
Thumbs up = "OK; I am all right; I understand"
Thumbs down = "No; negative"

☐ Horn

☐ Siren

☒ Other Cellular telephone _____

In the event that an on-site emergency develops, the procedures delineated in Table 7 are to be followed immediately.

11. CONFINED SPACE ENTRY ☐ APPLICABLE ☒ NOT APPLICABLE

The task(s) for this project involve confined-space entry. Workers must adhere to the company's Confined Space Entry Program [29 CFR §1910.120(j)].

12. SPILL CONTAINMENT ☒ APPLICABLE ☐ NOT APPLICABLE

The task(s) for this project involve drum/container sampling, excavation, transportation, etc. Workers must adhere to the hazard mitigator for drum handling in Attachment C.

13. HAZARD COMMUNICATION ☒ APPLICABLE ☐ NOT APPLICABLE

The following procedures must be followed for all chemicals brought on site (i.e., decontamination solution, sampling preservatives, KB-1 Solution, Sodium Permanganate, etc.):

- Labels on incoming primary chemical containers must not be defaced.
- Chemical containers must be stored in appropriate storage cabinets.

- Secondary containers and storage cabinets must be correctly and clearly labeled using the Hazardous Materials Identification System (HMIS).
- Incompatible chemicals must not be stored together.
- Workers have received training on the hazards of these chemicals as indicated in Table 2.
- A Material Safety Data Sheet (MSDS) for each chemical must be included in Attachment G.

When chemicals are used on site, workers must adhere to the company's Hazard Communication Program (29 CFR §1910.1200).

Figure 1

**Site Map
(next page)**

WRITTEN DIRECTIONS TO SITE:

Interstate 39 North to Route 6. Exit on Route 6 heading West. Go past Union
Street and past Sterling Street to Laharpe Street. Head North on Laharpe Street.
Go to 8th Street and head East on 8th Street. The facility is located at 1500 8th Street,
LaSalle, LaSalle County, Illinois.

Carus Corporation telephone number: 815-224-6850

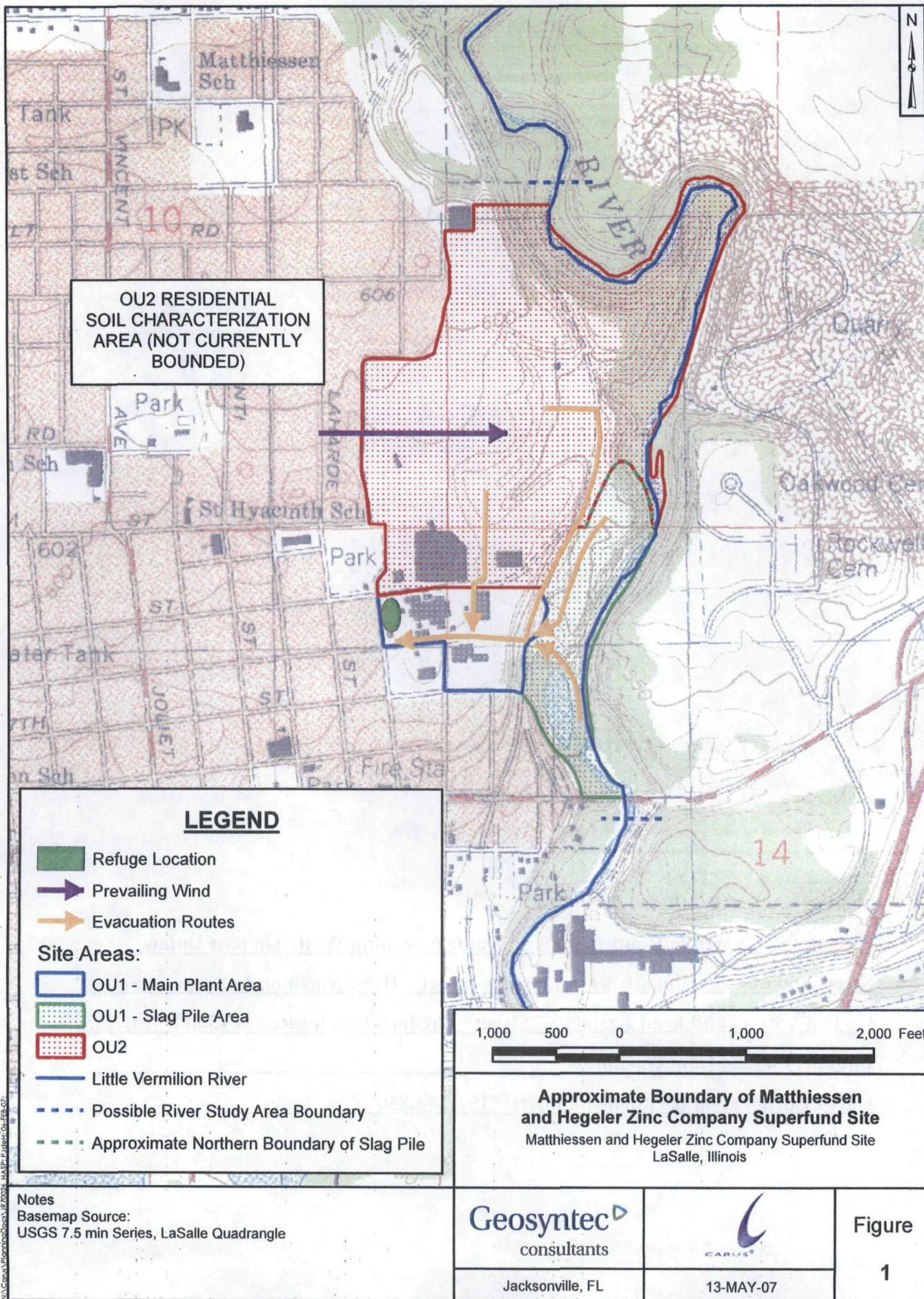


Table 1

Key Personnel and Health & Safety Responsibilities

<i>Principal-in-Charge or Associate-in-Charge Tom Peel</i>	<i>Project Manager (PM) Nandra Weeks</i>	<i>Site Health & Safety Officer (SHSO) Brad Bodine</i>	<i>Project Personnel Various</i>	<i>Environmental, Health & Safety Coordinator (EHSC) James Griffin</i>
<ul style="list-style-type: none"> • Approve this HASP and amendments, if any. • Ultimately responsible that elements of this HASP are implemented. 	<ul style="list-style-type: none"> • Approve this HASP and amendments, if any. • Monitor the field log books for health and safety work practices employed. • Coordinate with SHSO so that emergency response procedures are implemented. • Verify corrective actions are implemented. • See to it that personnel receive this plan, are aware of its provisions, are aware of the potential hazards associated with site operations, are instructed in safe work practices, are familiar with emergency response procedures, and that this is documented. • Provide for appropriate monitoring, personal protective equipment, and decontamination materials. 	<ul style="list-style-type: none"> • Prepare and implement project (HASP) and amendments, if any, and report to the Project Manager for action if any deviations from the anticipated conditions exist, and authorize the cessation of work if necessary. • Confirm that site personnel meet the training and medical requirements. • Conduct pre-entry briefing and daily tailgate safety meetings. • Verify that all monitoring equipment and personal protective equipment is operating correctly according to manufacturer's instructions and such equipment is utilized by on-site personnel. Calibrate or verify calibration of all monitoring equipment and record results. • Verify that decontamination procedures are being implemented. • Implement site emergency response and follow-up procedures. • Notify the EHSC in the event an emergency occurs. • Performs weekly inspections 	<ul style="list-style-type: none"> • Provide verification of required health and safety training and medical surveillance prior to arriving at the site. • Notify the SHSO of any special medical conditions (e.g., allergies). • Attend pre-entry briefings and daily tailgate safety meetings. • Immediately report any accidents and/or unsafe conditions to the SHSO. • Be familiar with and abide by the HASP. • Individuals are responsible for their own safety. 	<ul style="list-style-type: none"> • Review and audit HASP and amendments • Maintain a copy of the cover sheet of each completed HASP. • Notify Director of Environment, Health & Safety in the event an emergency occurs. • Assist with the implementation of the corporate health and safety program. • Consult on health and safety issues.

Table 2

Training / Medical Surveillance / Respirator Fit Test Records

[illegible]

Footnotes:

¹ CPR Refresher: every year; First Aid Refresher: every three years.

² Annual Medical Surveillance for EH&S Category I, Biannual Medical Surveillance for EH&S Categories II & III.

³ For EH&S Categories I & II only.

⁴ Could include task-specific training project-specific training, or project-specific medical surveillance.

Table 3

General Safe Work Practices

- Minimize contact with excavated or contaminated materials. Do not place equipment on the ground. Do not sit or kneel on potentially contaminated surfaces.
- Smoking, eating, or drinking after entering the work zone and before decontamination must not be allowed. Employees who are suspected of being under the influence of illegal drugs or alcohol will be removed from the site. Workers taking prescribed medication that may cause drowsiness should not be operating heavy equipment, and should be prohibited from performing tasks where Level C, B, or A personal protective equipment is required.
- Practice good housekeeping. Keep everything orderly and out of potentially harmful situations.
- Use of contact lenses on-site must not be allowed when dictated by working conditions.
- The following conditions must be observed when operating a motor vehicle.
 - Wearing of seat belts is mandatory
 - During periods of rain, fog, or other adverse weather conditions, the use of headlights is mandatory
 - A backup warning system or use of vehicle horn is mandatory when the vehicle is engaged in a backward motion
 - All posted traffic signs and directions from flagmen must be observed
 - Equipment and/or samples transported in vehicles must be secured from movement
 - The use of GeoSyntec acquired vehicles by non-GeoSyntec personnel is prohibited
- In an unknown situation, always assume the worst conditions.
- Be observant of your immediate surroundings and the surroundings of others. It is a team effort to notice and warn of impending dangerous situations. Withdrawal from a hazardous situation to reassess procedures is the preferred course of action.
- Conflicting situations may arise concerning safety requirements and working conditions and must be addressed and resolved rapidly by the SHSO and PM to relieve any motivations or pressures to circumvent established safety policies.
- Unauthorized breaches of specified safety protocol must not be allowed. Workers unwilling or unable to comply with the established procedures must be discharged.

Table 4
Contaminants of Concern

<i>Contaminant</i>	<i>Medium¹</i>	<i>Maximum Concentration²</i>	<i>EPA Region 9 PRGs for Tap Water³</i>	<i>EPA Region 9 PRGs for Soil⁴</i>
Arsenic	slag	245 mg/kg	N/A	0.39 mg/kg Residential 1.60 mg/kg Industrial
Chromium	slag	98 mg/kg	N/A	30 mg/kg Residential 64 mg/kg Industrial
Iron	slag	209,000 mg/kg	N/A	23,000 mg/kg Residential 100,000 mg/kg Industrial
Lead	slag	38,700 mg/kg	N/A	400 mg/kg Residential 800 mg/kg Industrial
Manganese	slag	40,600 mg/kg	N/A	1,800 mg/kg Residential 19,000 mg/kg Industrial
Arsenic	soil	27 mg/kg	N/A	0.39 mg/kg Residential 1.60 mg/kg Industrial
Lead	soil (road gravel)	3,660 mg/kg	N/A	400 mg/kg Residential 800 mg/kg Industrial
Manganese	soil	118,000 mg/kg	N/A	1,800 mg/kg Residential 19,000 mg/kg Industrial

Footnotes:

N/A = not applicable

¹ Indicate type of medium (i.e. soil, water, sludge, etc.).

² Indicate the maximum concentration detected for the contaminant. Indicate liquids in µg/l and solids in mg/kg.

³ For liquids, regulatory remediation criteria used are EPA Region 9 Preliminary Remediation Goals (PRGs) for Tap Water. USEPA Maximum Contaminant Level (MCL) used for lead.

⁴ For solids, regulatory remediation criteria used are EPA Region 9 PRGs for soil.

Table 4
Contaminants of Concern

<i>Contaminant</i>	<i>Medium¹</i>	<i>Maximum Concentration²</i>	<i>EPA Region 9 PRGs for Tap Water³</i>	<i>EPA Region 9 PRGs for Soil⁴</i>
Benzene	water	0.87 mg/l	0.00035 mg/l	N/A
Trichloroethene	water	0.031 mg/l	0.000028 mg/l	N/A
Xylenes	water	1.4 mg/l	0.21 mg/l	N/A
bis(2-Ethylhexyl) phthalate	water	0.0070 mg/l	0.0048 mg/l	N/A
Naphthalene	water	0.045 mg/l	0.0062 mg/l	N/A
Aluminum	water	123 mg/l	36 mg/l	N/A
Antimony	water	0.081 mg/l	0.015 mg/l	N/A
Arsenic	water	0.022 mg/l	0.000045 mg/l	N/A

Footnotes:

N/A = not applicable

¹ Indicate type of medium (i.e. soil, water, sludge, etc.).

² Indicate the maximum concentration detected for the contaminant. Indicate liquids in µg/l and solids in mg/kg.

³ For liquids, regulatory remediation criteria used re EPA Region 9 Preliminary Remediation Goals (PRGs) for Tap Water. USEPA Maximum Contaminant Level (MCL) used for lead.

⁴ For solids, regulatory remediation criteria used are EPA Region 9 PRGs for soil.

Table 4
Contaminants of Concern

<i>Contaminant</i>	<i>Medium</i> ¹	<i>Maximum Concentration</i> ²	<i>EPA Region 9 PRGs for Tap Water</i> ³	<i>EPA Region 9 PRGs for Soil</i> ⁴
Cadmium	water	2.2 mg/l	0.018 mg/l	N/A
Chromium	water	0.25 mg/l	0.11 mg/l	N/A
Iron	water	208 mg/l	11 mg/l	N/A
Lead	water	2.2 mg/l	0.015 mg/l	N/A
Manganese	water	25 mg/l	0.88 mg/l	N/A
Vanadium	water	0.25 mg/l	0.036 mg/l	N/A
Zinc	water	831 mg/l	11 mg/l	N/A

Footnotes:

N/A = not applicable

¹ Indicate type of medium (i.e. soil, water, sludge, etc.).

² Indicate the maximum concentration detected for the contaminant. Indicate liquids in µg/l and solids in mg/kg.

³ For liquids, regulatory remediation criteria used are EPA Region 9 Preliminary Remediation Goals (PRGs) for Tap Water. USEPA Maximum Contaminant Level (MCL) used for lead.

⁴ For solids, regulatory remediation criteria used are EPA Region 9 PRGs for soil.

Table 4
Contaminants of Concern

<i>Contaminant</i>	<i>Medium</i> ¹	<i>Maximum Concentration</i> ²	<i>EPA Region 9 PRGs for Tap Water</i> ³	<i>EPA Region 9 PRGs for Soil</i> ⁴
Arsenic	sediment	38 mg/kg	N/A	0.39 mg/kg Residential 1.60 mg/kg Industrial
Cadmium	sediment	47 mg/kg	N/A	37 mg/kg Residential 450 mg/kg Industrial
Chromium	sediment	280 mg/kg	N/A	30 mg/kg Residential 64 mg/kg Industrial
Lead	sediment	1,050 mg/kg	N/A	400 mg/kg Residential 800 mg/kg Industrial

Footnotes:

N/A = not applicable

¹ Indicate type of medium (i.e. soil, water, sludge, etc.).

² Indicate the maximum concentration detected for the contaminant. Indicate liquids in µg/l and solids in mg/kg.

³ For liquids, regulatory remediation criteria used are EPA Region 9 Preliminary Remediation Goals (PRGs) for Tap Water. USEPA Maximum Contaminant Level (MCL) used for lead.

⁴ For solids, regulatory remediation criteria used are EPA Region 9 PRGs for soil.

Table 5
Hazard Analysis

TASKS	
① Slag waste material and soil sampling	⑤ Well boring and installation
② Boring installation (hand auger and drill rig)	⑥ Groundwater sampling
③ Trenching	⑦
④ Sediment and surface water sampling	⑧

	①	②	③	④	⑤	⑥	⑦	⑧
I. Chemical Hazards								
Fire								
Inhalation (Dust)	x	x	x		x			
Permanganate Handling								
Reactivity						x		
Skin absorption	x	x	x	x	x	x		
II. Physical Hazards								
Boating				x				
Chainsaw								
Cold Stress	x	x	x	x	x	x		
Compressed Gas Cylinder								
Downhole Logging								
Drilling (including Indoor)		x			x			
Drum and Container Handling		x			x	x		
Electrocution		x	x		x			
Excavation/Trenching			x					
Eye Injury	x	x	x	x	x	x		
Fall Protection								
Flash flood				x				
Hand/Foot Injury	x	x	x	x	x	x		
Heat Stress	x	x	x	x	x	x		

Table 5
Hazard Analysis
(continued)

II. Physical Hazards (continued)									
Heavy Equipment		x	x		x	x			
Helicopter									
Lifting Heavy Loads	x	x	x	x	x	x			
Lockout/Tagout									
Noise		x	x		x	x			
Nuclear Gauge Radiation Exposure									
Portable Power/Hand Tool		x			x	x			
Slips, Trips, and Falls	x	x	x	x	x	x			
Thoroughfares									
Welding and Cutting		x			x				
Other:									
III. Biological Hazards									
Allergic Reaction to Poisonous Plants	x	x	x	x	x	x			
Bees	x	x	x	x	x	x			
Dogs									
Insect/Vermin/Snake Bites	x	x	x	x	x	x			
Medical Waste									
Mountain Lions									
Other:									

Instructions: For each task, place an "X" in the blank corresponding to associated hazards.

Table 6
Emergency Response Contacts

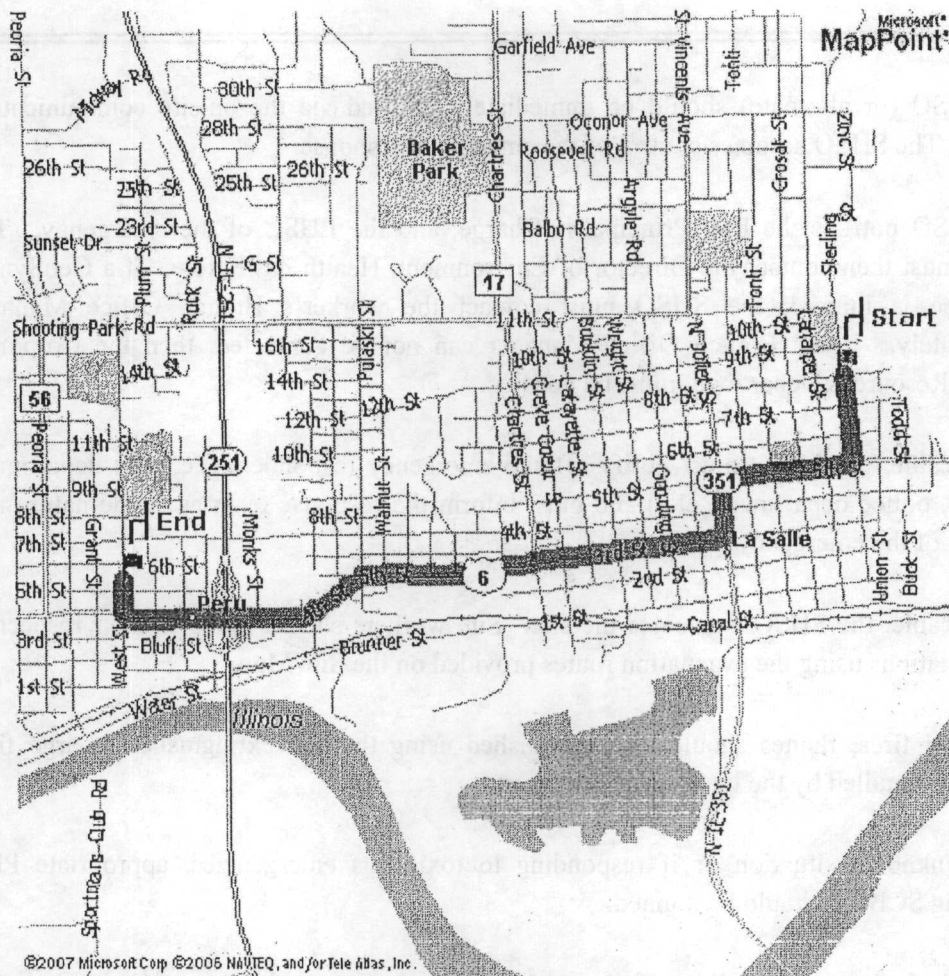
<i>Name</i>	<i>Telephone Numbers</i>		<i>Date of Pre-Emergency Notification</i>
	<i>Office</i>	<i>Mobile</i>	
Fire Department - 911	(815) 224-0834	N/A	
Hospital – 911 Illinois Valley Community Hospital	(815) 224-1307	N/A	
Police Department - 911	(815) 223-2131	N/A	
Branch Office Manager – Peter Zeeb	(978) 263-9588	(617) 283-4517	
Corporate Human Resources Director - <i>Mary Masty</i>	(561) 922-1005	(954) 224-8415	
Project Manager - Nandra Weeks	(904) 388-8821	(904) 626-0866	
Principal-in-Charge – Tom Peel	(561) 995-0900	(561) 251-1925	
Environmental, Health & Safety Coordinator - James Griffin	(904) 388-8821	(904) 591-4634	
Director of Environment, Health & Safety - <i>Jack C. Peng, Ph.D.</i>	(925) 788-6828	(925) 788-6828	
USEPA - Demaree Collier	(312) 886-0214	N/A	
Illinois EPA - Tom Williams	(815) 223-1714	N/A	
Carus Corporation – Paul Carus	(815) 224-6850	N/A	

N/A = not applicable

WRITTEN DIRECTIONS TO HOSPITAL:

See next page.

Route with Map and Directions



1. Depart Start on Sterling St (South) (Distance: 0.22 miles; Duration: 0 minutes)
2. Turn RIGHT (West) onto US-6 [5th St] (Distance: 0.37 miles; Duration: 1 minutes)
3. Turn LEFT (South) onto US-6 [SR-351] (Distance: 0.15 miles; Duration: 0 minutes)
4. Turn RIGHT (West) onto US-6 [3rd St] (Distance: 0.61 miles; Duration: 0 minutes)
5. Keep STRAIGHT onto US-6 [5th St] (Distance: 0.37 miles; Duration: 0 minutes)
6. Keep STRAIGHT onto US-6 [4th St] (Distance: 0.68 miles; Duration: 1 minutes)
7. Turn RIGHT (North) onto West St (Distance: 0.09 miles; Duration: 0 minutes)
8. Arrive End (Distance: 0 miles; Duration: 0 minutes)

Total Distance: 2.49 miles

Total Trip Time: 5 minutes

Table 7

Emergency Response Procedures

- The SHSO (or alternate) should be immediately notified via the on-site communication system. The SHSO assumes control of the emergency response.
- The SHSO notifies the PM, Principal-in-Charge, and the EHSC of the emergency. The EHSC must then contact the Director of Environment, Health & Safety. If a GeoSyntec employee is injured, the SHSO must contact the worker's Branch Office Manager immediately. If the Branch Office Manager can not be contacted, then the Corporate Human Resources Department must be notified.
- If applicable, the SHSO must notify off-site emergency responders (i.e., fire department, hospital, police department, etc.) and must inform the response team as to the nature and location of the emergency on site.
- If applicable, the SHSO evacuates the site. Site workers should move to their respective refuge stations using the evacuation routes provided on the Site Map.
- For small fires, flames should be extinguished using the fire extinguisher. Large fires should be handled by the local fire department.
- In an unknown situation or if responding to toxic gas emergencies, appropriate PPE, including SCBAs, should be donned.
- If chemicals are accidentally spilled or splashed into eyes or of skin, use eyewash and/or shower.
- Before continuing site operations after an emergency involving toxic gases, the SHSO will don a SCBA and utilize appropriate air monitoring equipment to verify that the site is safe.
- An injured worker must be decontaminated appropriately.
- If a worker is injured, first aid will be administered by workers certified in first aid.
- After the response, the injured employee and his/her supervisor/manager must complete reports of accident and illness obtained from the Branch Office Manager.
- Director of EHS will discuss each reported case during the annual HAZWOPER refresher with the entire workforce.

ATTACHMENT A

Attachment A

Weekly Health & Safety Inspection Checklist

Project: _____ Date: _____	
Inspected by: _____	
<i>Category</i>	<i>Observations/Corrective Actions (N/A, if Not Applicable)</i>
Pre-entry briefing records are current	
Tailgate meeting records are current	
Training/medical surveillance/respiratory protection records are current	
Site map is posted	
Buddy system is implemented	
Work zones are identified	
Site access is controlled	
Visitors are being escorted	
On-site/off-site communications are in working order	
Safe work practices are being implemented	
Any additional hazards incurred?	
Air monitoring equipment is in working condition	
Air monitoring records are being recorded in field log book	
Air monitoring calibration records are being recorded in field log book	
PPE storage area is neat and organized	
Standard operating procedures are being implemented	
Housekeeping at decontamination zone is appropriate	
Decontamination procedures are being implemented	
Emergency response equipment is in working condition	
Route to hospital is posted	
Confined space entry program is being implemented	
Spill containment equipment is available	
Chemical inventory is up to date	
Material safety data sheets are available	
Primary and secondary containers are properly labeled	
Housekeeping at the chemical storage area is appropriate	

ATTACHMENT B

Attachment B

Contaminant Fact Sheet Directory

<i>Included in HASP</i>	<i>Chemical Name</i>	<i>Synonyms</i>	<i>Document Number</i>
<input type="checkbox"/>	Acetone	Dimethyl Ketone; Ketone propane; 2-Propanone	GA971212
<input type="checkbox"/>	Aldrin	HHDN; Octalene	GA980283
<input type="checkbox"/>	Aniline	Aminobenzene; Aniline Oil; Benzeneamine; Phenylamine	GA980093
<input checked="" type="checkbox"/>	Arsenic	Arsenic metal; Arsenia	GA981097
<input checked="" type="checkbox"/>	Benzene	Benzol; Phenyl hydride	GA970125
<input checked="" type="checkbox"/>	Bis(2-ethylhexyl)phthalate	Di(2-ethylhexyl)phthalate	GA970207
<input checked="" type="checkbox"/>	Cadmium	Cadmium metal	GA970126
<input type="checkbox"/>	Carbon disulfide	Carbon bisulfide	GA970832
<input type="checkbox"/>	Chlorobenzene	Benzene chloride; Chlorobenzyl; MCB; Phenyl chloride	GA970127
<input type="checkbox"/>	Chloroform	Methane trichloride; Trichloromethane	GA970128
<input type="checkbox"/>	Chromic Acid	Chromic anhydride; Chromium trioxide	GA980758
<input checked="" type="checkbox"/>	Chromium	Chromium metal	GA970129
<input type="checkbox"/>	Copper	Copper metal dusts; Copper metal mists	GA980756
<input type="checkbox"/>	2,4-D	Dichlorophenoxyacetic acid	GA971255
<input type="checkbox"/>	DDT	p,p-DDT; Dichlorodiphenyltrichloroethane; 1,1,1-Trichloro-2,2-bis(p-chlorophenyl)ethane	GA980284
<input type="checkbox"/>	1,2-Dichlorobenzene	O-DCB; Orthodichlorobenzene	GA970130

Attachment B

Contaminant Fact Sheet Directory (continued)

<i>Included in HASP</i>	<i>Chemical Name</i>	<i>Synonyms</i>	<i>Document Number</i>
<input type="checkbox"/>	1,2-Dichloroethane	Ethylene dichloride; Glycol dichloride	GA970954
<input type="checkbox"/>	1,2-Dichloroethylene	1,2-Dichloroethene; (cis, trans, or sym-) Acetylene dichloride	GA970953
<input type="checkbox"/>	1,2-Dichloropropane	Propylene dichloride; Dichloro-1,2- propane	GA970131
<input type="checkbox"/>	2,4-Dinitrotoluene	Dinitrotoluene; DNT; Methyldinitrobenzene	GA990071
<input type="checkbox"/>	Endosulfan	Benzoepin; Endosulphan ; Thiodan	GA971257
<input type="checkbox"/>	Ethylbenzene	Ethylbenzol; Phenylethane	GA970132
<input type="checkbox"/>	Ethylene Dibromide	EDB; 1,2-Dibromoethane, Ethylene bromide, Glycol dibromide	GA980285
<input type="checkbox"/>	Gasoline	Motor fuel; Motor spirits; Natural gasoline; Petrol	GA970833
<input type="checkbox"/>	Hexachloroethane	Carbon hexachloride; Ethane hexachloride; Perchloroethane	GA971252
<input type="checkbox"/>	Hydrochloric Acid	Anhydrous hydrogen chloride; Aqueous hydrogen chloride; Muriatic acid	GA980757
<input type="checkbox"/>	Hydrogen Sulfide	Hydrosulfuric acid; Sewer gas; Sulfuretted hydrogen	GA980399
<input type="checkbox"/>	Isophorone	Isoacetophorone; 3,5,5-Trimethyl 2- cyclohexenone	GA971253
<input type="checkbox"/>	Isopropanol	Isopropyl alcohol; IPA; 2-Propanol	GA970133
<input checked="" type="checkbox"/>	Lead (inorganic)	Lead metal	GA970134
<input type="checkbox"/>	Mercury	Colloidal mercury; Metallic mercury; Quicksilver	GA970135
<input type="checkbox"/>	Methane	Fire damp; Marsh gas; Methyl hydride	GA970834
<input type="checkbox"/>	Methoxychlor	P,p-Dimethoxydiphenyl/trichlorethane; DMDY	GA971256
<input type="checkbox"/>	2-Methylphenol	Ortho-Cresol; 2-Cresol; O-Cresylic Acid; 1-Hydroxy-2-Methylbenzene; 2- Hydroxytoluene	GA980091

Attachment B

Contaminant Fact Sheet Directory (continued)

<i>Included in HASP</i>	<i>Chemical Name</i>	<i>Synonyms</i>	<i>Document Number</i>
<input type="checkbox"/>	Methyl ethyl ketone	2-Butanone; MEK; Methyl acetone	GA970136
<input type="checkbox"/>	Methyl chloroform	1,1,1-Trichloroethane	GA970137
<input type="checkbox"/>	Methylene chloride	Dichloromethane; Methylene Dichloride	GA970138
<input checked="" type="checkbox"/>	Naphthalene	Naphthalin; Tar Camphor; White Tar	GA970139
<input type="checkbox"/>	Nickel	Nickel catalyst	GA980759
<input type="checkbox"/>	Nitroaniline	Para-aminonitrobenzene; 4-Nitroaniline; 4-Nitrobenzenamine; p- Nitrophenylamine, PNA	GA980094
<input type="checkbox"/>	Nitrobenzene	Essence of mirbane; Nitrobenzol; Oil of mirbane	GA980095
<input type="checkbox"/>	Pentachlorophenol	PCP; Penta; 2,3,4,5,6- Pentachlorophenol	GA970140
<input type="checkbox"/>	Phenol	Carbonic acid; Hydroxybenzene; Monohydroxybenzene; Phenol alcohol; Phenyl hydroxide	GA971250
<input type="checkbox"/>	Phosgene	Carbonyl chloride; Carbon oxychloride; Chloroformyl chloride	GA990069
<input type="checkbox"/>	Polychlorinated biphenyls (54%)	PCBs; Chlorodiphenyl	GA970141
<input type="checkbox"/>	Silver	Silver metal; Argentum	GA970142
<input type="checkbox"/>	2,4,5-T	2,4,5-Trichlorophenoxyacetic acid	GA971254
<input type="checkbox"/>	Tetrachloroethylene	Tetrachloroethylene; Perchlorethylene; Perk	GA971274
<input type="checkbox"/>	o-Toluidene	2-Methybenzeneamine; O- Aminotoluene; 1-Methyl-2- aminobenzene; O-Methylaniline; 2- Methylaniline, ortho-Toluidine	GA980096
<input type="checkbox"/>	Toluene	Methyl benzene; Methyl benzol	GA970143
<input type="checkbox"/>	Toluene-2,4- Diisocyanate	TDI; 2,4-TDI; 2,4-Toluene diisocyanate	GA990070

Attachment B

Contaminant Fact Sheet Directory (continued)

<i>Included in HASP</i>	<i>Chemical Name</i>	<i>Synonyms</i>	<i>Document Number</i>
<input type="checkbox"/>	Toxaphene	Chlorinated camphene	GA970153
<input type="checkbox"/>	1,1,2-Trichloroethane	Ethane trichloride; B-Trichloroethane; Vinyl trichloride	GA971249
<input type="checkbox"/>	1,2,4-Trichlorobenzene	Trichlorobenzene; 1,2,4- Trichlorobenzel	GA971251
<input checked="" type="checkbox"/>	Trichloroethene	Trichloroethylene; TCE	GA970145
<input type="checkbox"/>	Trichlorofluoromethane	Fluorotrichloromethane; Freon II	GA970144
<input type="checkbox"/>	1,2,3-Trichloropropane	Allyl trichloride, Glycerol trichlorohydrin, Glyceryl trichlorohydrin; Trichlorohydrin	GA980286
<input type="checkbox"/>	Vinyl chloride	Chloroethene; VC; VCM	GA970146
<input checked="" type="checkbox"/>	Xylene (Mixed Isomers)	o-xylene; p-xylene; m-xylene	GA970147

CONTAMINANT FACT SHEET - ARSENIC

CAS Number: 7440-38-2		Molecular Weight: 74.92		Color: silvery to black		Ionization Potential (eV): NA		Vapor Density (Air=1): NA																	
Synonyms: Arsenic metal; Arsenia		Physical State: solid		Odor: odorless		Henry's Constant: NA {(atm × m ³ /mol)}		Vapor Pressure: 1 (mm.Hg.at.20°C)																	
Fire Hazard NFPA rating: 3 HMIS rating: 2		Reactivity Hazard NFPA rating: 2 HMIS rating: 2		Health Hazard		NFPA rating: 3 HMIS rating: 3																			
Flash Point(°F): NA LEL(%): NA UEL(%): NA Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input checked="" type="checkbox"/> Foam <input checked="" type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Gas <input type="checkbox"/> Combustible Liquid		Incompatibilities: Bromates, peroxides, chlorates, isodates, lithium, silver nitrate, potassium nitrate, potassium permanganate, chromium (VI) oxide, halogens, bromine azide, pulladium, dirubidium acetylde, zinc, and platinum DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): NA IDLH (mg/m ³): 500 mg/m ³ <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source (mg/m³)</td> <td>(mg/m³)</td> <td>(mg/m³)</td> <td>(mg/m³)</td> </tr> <tr> <td>OSHA PELs</td> <td>0.5* 0.01**</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>0.01</td> <td>NA</td> <td>NA</td> </tr> </tbody> </table> * = Organic Compounds ** = Inorganic Compounds Signs/Symptoms of Acute Exposure: <u>Inhalation may cause conjunctivitis; eyelid edema; nasal irritation; coughing; chest pain; inflammation of the mouth.</u> DOT: <input checked="" type="checkbox"/> Poison			TWA	STEL	C	Source (mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)	OSHA PELs	0.5* 0.01**	NA	NA	ACGIH TLVs	0.01	NA	NA	Carcinogenic: OSHA: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> Not listed IARC: <input checked="" type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input checked="" type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input type="checkbox"/> Not listed ACGIH: <input checked="" type="checkbox"/> A1 <input type="checkbox"/> A2 <input type="checkbox"/> A3 <input type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive			
	TWA	STEL	C																						
Source (mg/m ³)	(mg/m ³)	(mg/m ³)	(mg/m ³)																						
OSHA PELs	0.5* 0.01**	NA	NA																						
ACGIH TLVs	0.01	NA	NA																						
Air Monitoring																									
Type		Brand/Model No.			Calibration Method/Media																				
<input type="checkbox"/> Explosimeter		Gastech GX-82			Methane																				
<input type="checkbox"/> PID		MiniRAE			Isobutylene																				
<input type="checkbox"/> FID		Foxboro OVA			Methane																				
<input type="checkbox"/> Colorometric Tubes		Drager			Check pump for leaks																				
<input type="checkbox"/> Chemical Monitor <input type="checkbox"/> Dust Monitor		NA			NA																				
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#			Calibrate pump w/ media																				
Protective Clothing																									
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North		<input checked="" type="checkbox"/> Viton/Best		<input checked="" type="checkbox"/> Silvershield/North		<input checked="" type="checkbox"/> 4H/Safety																	
		<input checked="" type="checkbox"/> Neoprene/Mapa		<input checked="" type="checkbox"/> Neoprene/Ans.Ed.		<input checked="" type="checkbox"/> Neoprene/BestUltraflex		<input checked="" type="checkbox"/> Neoprene/BestNeo.																	
		<input checked="" type="checkbox"/> PVC/Ans.Ed.		<input checked="" type="checkbox"/> PVC/BestHustler		<input checked="" type="checkbox"/> Nitrile/LabSafe.		<input checked="" type="checkbox"/> Nitrile/Ans.Ed.																	
		<input checked="" type="checkbox"/> Butyl/North		<input checked="" type="checkbox"/> PVA/Ans.Ed. <input type="checkbox"/> Other																					
Suit Type (Breakthrough >1hr unless noted):		<input checked="" type="checkbox"/> Tyvek		<input checked="" type="checkbox"/> Tyvek QC		<input checked="" type="checkbox"/> Tyvek/Saranex		<input checked="" type="checkbox"/> Tychem7500																	
						<input checked="" type="checkbox"/> Tychem 9400		<input checked="" type="checkbox"/> Tychem10,000 <input type="checkbox"/> Other																	
Respiratory Protection																									
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: HEPA			Full face: HEPA																		
Notes:																									
Prepared by: Sherry Hall					Date: 16 January 1997, Rev. 28 January 2002																				

CONTAMINANT FACT SHEET - BENZENE

CAS Number: 71-43-2		Molecular Weight: 78.1		Color: Colorless to Lt. Yellow		Ionization Potential (eV): 9.24		Vapor Density (Air=1): 2.7																	
Synonyms: Benzol; Phenyl hydride		Physical State: Liquid		Odor: Aromatic		Henry's Constant: 0.23		Vapor Pressure: 75 (mmHg@20°C)																	
Fire Hazard NFPA rating: 3 HMIS rating: 3		Reactivity Hazard NFPA rating: 0 HMIS rating: 0		Health Hazard NFPA rating: 2 HMIS rating: 3																					
Flash Point(°F): 12 LEL(%): 1.2 UEL(%): 7.8 Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input checked="" type="checkbox"/> Foam <input type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input checked="" type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: <u>Strong oxidizers; many fluorides & perchlorates; nitric acid</u> DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): 34-114 IDLH (ppm): 500 <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source</td> <td>(ppm)</td> <td>(ppm)</td> <td>(ppm)</td> </tr> <tr> <td>OSHA PELs</td> <td>1*</td> <td>5*</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>.5</td> <td>2.5</td> <td>NA</td> </tr> </tbody> </table> <p>* Table Z-2 for exclusions in 29CFR 1910, 1028</p> Signs/Symptoms of Acute Exposure: <u>Irritation of eyes, skin, nose, & respiratory system; giddiness; headache; nausea; staggered gait</u> DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source	(ppm)	(ppm)	(ppm)	OSHA PELs	1*	5*	NA	ACGIH TLVs	.5	2.5	NA	Carcinogenic: OSHA: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> Not listed IARC: <input checked="" type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input checked="" type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input type="checkbox"/> Not listed ACGIH: <input checked="" type="checkbox"/> A1 <input type="checkbox"/> A2 <input type="checkbox"/> A3 <input type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive			
	TWA	STEL	C																						
Source	(ppm)	(ppm)	(ppm)																						
OSHA PELs	1*	5*	NA																						
ACGIH TLVs	.5	2.5	NA																						
Air Monitoring																									
Type		Brand/Model No.				Calibration Method/Media																			
<input checked="" type="checkbox"/> Explosimeter		GasTech GX-82				Methane																			
<input checked="" type="checkbox"/> PID		MiniRAE				Isobutylene																			
<input checked="" type="checkbox"/> FID		Foxboro OVA 128				Methane																			
<input checked="" type="checkbox"/> Colorimetric Tubes		Drager/6728561(0.5-10ppm)				Check pump for leaks																			
<input type="checkbox"/> Chemical Monitor <input type="checkbox"/> Dust Monitor																									
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#1500				Calibrate pump w/ media																			
Protective Clothing																									
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North		<input type="checkbox"/> Viton/Best		<input checked="" type="checkbox"/> Silvershield/North		<input checked="" type="checkbox"/> 4H/Safety																	
		<input type="checkbox"/> Neoprene/Mapa		<input type="checkbox"/> Neoprene/Ans.Ed.		<input type="checkbox"/> Neoprene/Best Ultraflex		<input type="checkbox"/> Neoprene/Best Neo.																	
		<input type="checkbox"/> PVC/Ans.Ed.		<input type="checkbox"/> PVC/Best Hustler		<input checked="" type="checkbox"/> Nitrile/LabSafe.(27min)		<input type="checkbox"/> Nitrile/Ans.Ed.																	
		<input checked="" type="checkbox"/> Butyl/North (31min)		<input type="checkbox"/> PVA/Ans.Ed.		<input type="checkbox"/> Other																			
Suit Type (Breakthrough >1hr unless noted):		<input type="checkbox"/> Tyvek		<input type="checkbox"/> Tyvek QC		<input type="checkbox"/> Tyvek/Saranex		<input checked="" type="checkbox"/> Tychem 7500 (49min)																	
						<input checked="" type="checkbox"/> Tychem 9400		<input type="checkbox"/> Tychem 10,000																	
								<input type="checkbox"/> Other																	
Respiratory Protection																									
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm):			Half mask: 10 Full face: 50																		
Notes: Poor warning but OSHA allows Air Purifying Respirators																									
Prepared by: Sherry Hall																									
Date: 16 January 1997, Rev. 24 January 2002																									

CONTAMINANT FACT SHEET - BIS(2-ETHYLHEXYL)PHTHALATE

CAS Number: 117-81-7		Molecular Weight: 390.5		Color: Colorless		Odor: Slight odor																	
Synonyms: Di(2-ethylhexyl)phthalate; DEHP; Di-sec octyl phthalate		Physical State: Oily liquid		Boiling Point: 341°C		Melting Point: 12.5°C																	
Fire Hazard	NFPA rating: 1 HMIS rating: 1	Reactivity Hazard	NFPA rating: 0 HMIS rating: 0	Health Hazard NFPA rating: 0 HMIS rating: 0																			
Flash Point(°F): 420 LEL(%): 0.3 UEL(%): NA Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input checked="" type="checkbox"/> Foam <input checked="" type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: <u>Nitrates; strong oxidizers; acids & alkalis</u> DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (mg/m ³): NA IDLH (mg/m ³): 5000 <table border="1"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source</td> <td>(mg/m³)</td> <td>(mg/m³)</td> <td>(mg/m³)</td> </tr> <tr> <td>OSHA PELs</td> <td>5</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>5</td> <td>NA</td> <td>NA</td> </tr> </tbody> </table> Signs/Symptoms of Acute Exposure: <u>Irritation of eyes & mucous membranes</u> DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source	(mg/m ³)	(mg/m ³)	(mg/m ³)	OSHA PELs	5	NA	NA	ACGIH TLVs	5	NA	NA	Carcinogenic: OSHA: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> Not listed IARC: <input type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input checked="" type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input type="checkbox"/> Known <input checked="" type="checkbox"/> Anticipated <input type="checkbox"/> Process <input type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input type="checkbox"/> A2 <input checked="" type="checkbox"/> A3 <input type="checkbox"/> A4 <input type="checkbox"/> A5 <input checked="" type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive	
	TWA	STEL	C																				
Source	(mg/m ³)	(mg/m ³)	(mg/m ³)																				
OSHA PELs	5	NA	NA																				
ACGIH TLVs	5	NA	NA																				
Air Monitoring																							
Type		Brand/Model No.		Calibration Method/Media																			
<input type="checkbox"/> Explosimeter																							
<input type="checkbox"/> PID																							
<input type="checkbox"/> FID																							
<input type="checkbox"/> Colorimetric Tubes																							
<input type="checkbox"/> Chemical Monitor <input type="checkbox"/> Dust Monitor																							
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#5020																					
Protective Clothing																							
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input type="checkbox"/> Viton/North <input type="checkbox"/> Neoprene/Mapa <input type="checkbox"/> PVC/Ans.Ed. <input type="checkbox"/> Butyl/North		<input type="checkbox"/> Viton/Best <input checked="" type="checkbox"/> Neoprene/Ans.Ed. <input type="checkbox"/> PVC/BestHustler <input checked="" type="checkbox"/> PVA/Ans.Ed. 30min		<input type="checkbox"/> Silvershield/North <input type="checkbox"/> Neoprene/BestUltraflex <input type="checkbox"/> Nitrile/LabSafe.																	
						<input type="checkbox"/> 4H/Safety <input type="checkbox"/> Neoprene/BestNeo. <input checked="" type="checkbox"/> Nitrile/Ans.Ed.																	
Suit Type (Breakthrough >1hr unless noted):		<input type="checkbox"/> Tyvek <input type="checkbox"/> Tyvek QC		<input type="checkbox"/> Tyvek/Saranex <input checked="" type="checkbox"/> Tychem7500		<input checked="" type="checkbox"/> Tychem 9400 <input type="checkbox"/> Tychem 10,000																	
Respiratory Protection																							
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: Dust/Mist Full face: Dust/Mist																			
Notes: Prepared by: Sherry Hall																							
Date: 10 February 1997, Rev. 5 March 2002																							

CONTAMINANT FACT SHEET - CADMIUM

CAS Number: 7440-43-9		Molecular Weight: 112.4		Color: Silver-white		Ionization Potential (eV): NA		Vapor Density (Air=1): NA																	
Synonyms: Cadmium metal		Physical State: Solid		Odor: Odorless		Henry's Constant: NA		Vapor Pressure: 0 (mmHg@20C)																	
Fire Hazard		Reactivity Hazard		Health Hazard		NFPA rating: 3 HMIS rating: 3																			
NFPA rating: 0 HMIS rating: 0 Flash Point(°F): NA LEL(%): NA UEL(%): NA Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input type="checkbox"/> Foam <input type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: Strong oxidizers; elemental sulfur, selenium & tellurium DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): NA IDLH (mg/m ³): 9 <table border="1"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source</td> <td>(mg/m³)</td> <td>(mg/m³)</td> <td>(mg/m³)</td> </tr> <tr> <td>OSHA PELs</td> <td>0.005 *</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>0.01 I 0.002 R</td> <td>NA</td> <td>NA</td> </tr> </tbody> </table> * = Table Z-2 for excursions in 29 CFR 1910.1027 I = Measured in inhalable fraction of the aerosol R = Measured as respirable fraction of the aerosol Signs/Symptoms of Acute Exposure: <u>Pulmonary edema; dyspnea; cough; tight chest; substernal pain; muscle aches; nausea; headache; chills; vomiting; diarrhea</u> DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source	(mg/m ³)	(mg/m ³)	(mg/m ³)	OSHA PELs	0.005 *	NA	NA	ACGIH TLVs	0.01 I 0.002 R	NA	NA	Carcinogenic: OSHA: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> Not listed IARC: <input checked="" type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input checked="" type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input checked="" type="checkbox"/> A2 <input type="checkbox"/> A3 <input type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive			
	TWA	STEL	C																						
Source	(mg/m ³)	(mg/m ³)	(mg/m ³)																						
OSHA PELs	0.005 *	NA	NA																						
ACGIH TLVs	0.01 I 0.002 R	NA	NA																						
Air Monitoring																									
Type		Brand/Model No.				Calibration Method/Media																			
<input type="checkbox"/> Explosimeter																									
<input type="checkbox"/> PID																									
<input type="checkbox"/> FID																									
<input type="checkbox"/> Colorimetric Tubes																									
<input type="checkbox"/> Chemical Monitor <input checked="" type="checkbox"/> Dust Monitor		MIE MiniRam				Factory calib. w/ AZ road dust																			
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#7048				Calibrate pump w/ media																			
Protective Clothing																									
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North		<input checked="" type="checkbox"/> Viton/Best		<input checked="" type="checkbox"/> Silvershield/North		<input checked="" type="checkbox"/> 4H/Safety																	
		<input checked="" type="checkbox"/> Neoprene/Mapa		<input checked="" type="checkbox"/> Neoprene/Ans.Ed.		<input checked="" type="checkbox"/> Neoprene/BestUltraflex		<input checked="" type="checkbox"/> Neoprene/BestNeo.(30min)																	
		<input checked="" type="checkbox"/> PVC/Ans.Ed.		<input checked="" type="checkbox"/> PVC/BestHustler		<input checked="" type="checkbox"/> Nitrile/LabSafe.		<input checked="" type="checkbox"/> Nitrile/Ans.Ed.																	
		<input checked="" type="checkbox"/> Butyl/North		<input checked="" type="checkbox"/> PVA/Ans.Ed.		<input type="checkbox"/> Other																			
Suit Type (Breakthrough >1hr unless noted):		<input checked="" type="checkbox"/> Tyvek		<input checked="" type="checkbox"/> Tyvek QC		<input checked="" type="checkbox"/> Tyvek/Saranex		<input checked="" type="checkbox"/> Tychem7500																	
						<input checked="" type="checkbox"/> Tychem 9400		<input checked="" type="checkbox"/> Tychem 10,000																	
								<input type="checkbox"/> Other																	
Respiratory Protection																									
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: HEPA				Full face: HEPA																	
Notes: ACGIH TLV-TWA: 0.002 mg/m3 respirable fraction; Powder is pyrophoric. Prepared by: Sherry Hall																									
Date: 16 January 1997, Rev. 28 January 2002																									

CONTAMINANT FACT SHEET - CHROMIUM

CAS Number: 7440-47-3		Molecular Weight: 52.0		Color: Blue-white	Ionization Potential (eV): NA	Vapor Density (Air=1): 1.79																
Synonyms: Chromium metal; Chrome		Physical State: Solid		Odor: Odorless	Henry's Constant: NA	Vapor Pressure: 0 (mmHg@20C)																
Fire Hazard	NFPA rating: 1 HMIS rating: 1	Reactivity Hazard	NFPA rating: 1 HMIS rating: 1	Health Hazard NFPA rating: 2 HMIS rating: 2																		
Flash Point(°F): NA LEL(%): NA UEL(%): NA Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input type="checkbox"/> Foam <input type="checkbox"/> Water Spray <input type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: <u>Strong oxidizers (such as hydrogen peroxide); alkalis</u> DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): NA IDLH (mg/m ³): 250 <table border="1" style="width:100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source</td> <td>(mg/m³)</td> <td>(mg/m³)</td> <td>(mg/m³)</td> </tr> <tr> <td>OSHA PELs</td> <td>1</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>0.5</td> <td>NA</td> <td>NA</td> </tr> </tbody> </table> Signs/Symptoms of Acute Exposure: <u>Irritation of eyes & skin</u> DOT: <input type="checkbox"/> Poison				TWA	STEL	C	Source	(mg/m ³)	(mg/m ³)	(mg/m ³)	OSHA PELs	1	NA	NA	ACGIH TLVs	0.5	NA	NA
	TWA	STEL	C																			
Source	(mg/m ³)	(mg/m ³)	(mg/m ³)																			
OSHA PELs	1	NA	NA																			
ACGIH TLVs	0.5	NA	NA																			
Carcinogenic: OSHA: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> Not listed IARC: <input type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input checked="" type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input checked="" type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input type="checkbox"/> A2 <input type="checkbox"/> A3 <input checked="" type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive																						
Air Monitoring																						
Type		Brand/Model No.		Calibration Method/Media																		
<input type="checkbox"/> Explosimeter																						
<input type="checkbox"/> PID																						
<input type="checkbox"/> FID																						
<input type="checkbox"/> Colorimetric Tubes																						
<input type="checkbox"/> Chemical Monitor <input checked="" type="checkbox"/> Dust Monitor		MIE MiniRam		Factory calib. w/ AZ road dust																		
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#7024		Calibrate pump w/ media																		
Protective Clothing																						
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North	<input checked="" type="checkbox"/> Viton/Best	<input checked="" type="checkbox"/> Silvershield/North	<input checked="" type="checkbox"/> 4H/Safety																	
	<input checked="" type="checkbox"/> Neoprene/Mapa	<input checked="" type="checkbox"/> Neoprene/Ans.Ed.	<input checked="" type="checkbox"/> Neoprene/BestUltraflex	<input checked="" type="checkbox"/> Neoprene/BestNeo.(30min)																		
	<input checked="" type="checkbox"/> PVC/Ans.Ed.	<input checked="" type="checkbox"/> PVC/BestHustler	<input checked="" type="checkbox"/> Nitrile/LabSafe.	<input checked="" type="checkbox"/> Nitrile/Ans.Ed.																		
	<input checked="" type="checkbox"/> Butyl/North	<input checked="" type="checkbox"/> PVA/Ans.Ed.	<input type="checkbox"/> Other																			
Suit Type (Breakthrough >1hr unless noted):		<input checked="" type="checkbox"/> Tyvek	<input checked="" type="checkbox"/> Tyvek QC	<input checked="" type="checkbox"/> Tyvek/Saranex	<input checked="" type="checkbox"/> Tychem7500	<input checked="" type="checkbox"/> Tychem 9400 <input checked="" type="checkbox"/> Tychem 10,000 <input type="checkbox"/> Other																
Respiratory Protection																						
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: HEPA Full face: HEPA																		
Notes: Chromium dust suspended in carbon dioxide is ignitable & explosive when heated.																						
Prepared by: Sherry Hall				Date: 16 January 1997, Rev. 28 January 2002																		

CONTAMINANT FACT SHEET - LEAD (INORGANIC)

CAS Number: 7439-92-1		Molecular Weight: 207.2		Color: Gray		Ionization Potential (eV): NA		Vapor Density (Air=1): NA																	
Synonyms: Lead Metal; Plumbum		Physical State: Solid		Odor: Odorless		Henry's Constant: NA		Vapor Pressure: 1.77 (mmHg@20C)																	
Fire Hazard NFPA rating: 1 HMIS rating: 1		Reactivity Hazard NFPA rating: 0 HMIS rating: 0		Health Hazard NFPA rating: 3 HMIS rating: 3																					
Flash Point(°F): NA LEL(%): NA UEL(%): NA Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input checked="" type="checkbox"/> Foam <input checked="" type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: <u>Strong oxidizers; hydrogen peroxide; acids</u> DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): NA IDLH (mg/m ³): 100 <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source</td> <td>(mg/m³)</td> <td>(mg/m³)</td> <td>(mg/m³)</td> </tr> <tr> <td>OSHA PELs</td> <td>0.05*</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>0.05</td> <td>NA</td> <td>NA</td> </tr> </tbody> </table> *See 29 CFR 1910.1025 Signs/Symptoms of Acute Exposure: <u>Weakness; lassitude; insomnia; facial pallor; pale eyes; anorexia; constipation; abdominal pain; colic; anemia; gingival lead line; tremors; irritated eyes</u> DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source	(mg/m ³)	(mg/m ³)	(mg/m ³)	OSHA PELs	0.05*	NA	NA	ACGIH TLVs	0.05	NA	NA	Carcinogenic: OSHA: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> Not listed IARC: <input type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input checked="" type="checkbox"/> Group 2B <input type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input checked="" type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input type="checkbox"/> A2 <input checked="" type="checkbox"/> A3 <input type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive			
	TWA	STEL	C																						
Source	(mg/m ³)	(mg/m ³)	(mg/m ³)																						
OSHA PELs	0.05*	NA	NA																						
ACGIH TLVs	0.05	NA	NA																						
Air Monitoring																									
Type		Brand/Model No.				Calibration Method/Media																			
<input type="checkbox"/> Explosimeter																									
<input type="checkbox"/> PID																									
<input type="checkbox"/> FID																									
<input type="checkbox"/> Colorimetric Tubes																									
<input type="checkbox"/> Chemical Monitor <input checked="" type="checkbox"/> Dust Monitor		MIE MiniRam				Factory calib. w/ AZ road dust																			
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#7082				Calibrate pump w/ media																			
Protective Clothing																									
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North		<input checked="" type="checkbox"/> Viton/Best		<input checked="" type="checkbox"/> Silvershield/North		<input checked="" type="checkbox"/> 4H/Safety																	
		<input checked="" type="checkbox"/> Neoprene/Mapa		<input checked="" type="checkbox"/> Neoprene/Ans.Ed.		<input checked="" type="checkbox"/> Neoprene/BestUltraflex		<input checked="" type="checkbox"/> Neoprene/BestNeo.(30min)																	
		<input checked="" type="checkbox"/> PVC/Ans.Ed.		<input checked="" type="checkbox"/> PVC/BestHustler		<input checked="" type="checkbox"/> Nitrile/LabSafe.		<input checked="" type="checkbox"/> Nitrile/Ans.Ed.																	
		<input checked="" type="checkbox"/> Butyl/North		<input checked="" type="checkbox"/> PVA/Ans.Ed.		<input type="checkbox"/> Other																			
Suit Type (Breakthrough >1hr unless noted):		<input checked="" type="checkbox"/> Tyvek		<input checked="" type="checkbox"/> Tyvek QC		<input checked="" type="checkbox"/> Tyvek/Saranex		<input checked="" type="checkbox"/> Tychem 7500																	
						<input checked="" type="checkbox"/> Tychem 9400		<input checked="" type="checkbox"/> Tychem 10,000																	
								<input type="checkbox"/> Other																	
Respiratory Protection																									
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: HEPA			Full face: HEPA																		
Notes: ACGIH TLV-TWA: 0.002 mg/m3 respirable fraction; Powder is pyrophoric. Prepared by: Sherry Hall Date: 16 January 1997, Rev. 29 January 2002																									

CONTAMINANT FACT SHEET - NAPHTHALENE

CAS Number: 91-20-3		Molecular Weight: 128.2		Color: Colorless to Brown		Ionization Potential (eV): 8.12		Vapor Density (Air=1): 4.4																	
Synonyms: Naphthalin; Tar Campor; White Tar		Physical State: Solid		Odor: Mothballs		Henry's Constant: 0.02		Vapor Pressure: 0.08 (mmHg@20°C)																	
Fire Hazard NFPA rating: 2 HMIS rating: 2		Reactivity Hazard NFPA rating: 0 HMIS rating: 0		Health Hazard		NFPA rating: 2 HMIS rating: 2																			
Flash Point(°F): 174 LEL(%): 0.9 UEL(%): 5.9 Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input type="checkbox"/> Foam <input type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: <u>Strong oxidizers; chromic anhydride</u> DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): 0.038 IDLH (ppm): 250 <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source (ppm)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>OSHA PELs</td> <td>10</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>10</td> <td>15</td> <td>NA</td> </tr> </tbody> </table> Signs/Symptoms of Acute Exposure: <u>Irritation of eyes; headache; confusion; excitement; nausea; vomiting; abdominal pain; irritated bladder; profuse sweating; dermatitis</u> DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source (ppm)				OSHA PELs	10	NA	NA	ACGIH TLVs	10	15	NA	Carcinogenic: OSHA: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> Not listed IARC: <input type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input checked="" type="checkbox"/> Not listed NTP: <input type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input checked="" type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input type="checkbox"/> A2 <input type="checkbox"/> A3 <input checked="" type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive			
	TWA	STEL	C																						
Source (ppm)																									
OSHA PELs	10	NA	NA																						
ACGIH TLVs	10	15	NA																						
Air Monitoring																									
Type		Brand/Model No.				Calibration Method/Media																			
<input checked="" type="checkbox"/> Explosimeter		GasTech GX-82				Methane																			
<input type="checkbox"/> PID																									
<input checked="" type="checkbox"/> FID		Foxboro OVA 128				Methane																			
<input type="checkbox"/> Colorimetric Tubes																									
<input type="checkbox"/> Chemical Monitor <input type="checkbox"/> Dust Monitor																									
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#1501				Calibrate pump w/ media																			
Protective Clothing																									
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input type="checkbox"/> Viton/North		<input type="checkbox"/> Viton/Best		<input type="checkbox"/> Silvershield/North		<input type="checkbox"/> 4H/Safety																	
		<input type="checkbox"/> Neoprene/Mapa		<input type="checkbox"/> Neoprene/Ans.Ed.		<input type="checkbox"/> Neoprene/BestUltraflex		<input type="checkbox"/> Neoprene/BestNeo.																	
		<input type="checkbox"/> PVC/Ans.Ed.		<input type="checkbox"/> PVC/BestHustler		<input type="checkbox"/> Nitrile/LabSafe.		<input type="checkbox"/> Nitrile/Ans.Ed.																	
		<input type="checkbox"/> Butyl/North		<input type="checkbox"/> PVA/Ans.Ed.		<input checked="" type="checkbox"/> Other																			
Suit Type (Breakthrough >1hr unless noted):		<input type="checkbox"/> Tyvek		<input type="checkbox"/> Tyvek QC		<input type="checkbox"/> Tyvek/Saranex		<input checked="" type="checkbox"/> Tychem7500																	
						<input type="checkbox"/> Tychem 9400		<input type="checkbox"/> Tychem 10,000																	
								<input type="checkbox"/> Other																	
Respiratory Protection																									
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: 100				Full face: 250																	
Notes: Glove Type/Brand information not available																									
Prepared by: Sherry Hall																									
Date: 16 January 1997, Rev. 30 January 2002																									

CONTAMINANT FACT SHEET - TRICHLOROETHENE

CAS Number: 79-01-6 Synonyms: Trichloroethylene; TCE		Molecular Weight: 131.4 Physical State: Liquid		Color: Colorless Odor: Chloroform-like		Ionization Potential (eV): 9.45 Henry's Constant: 0.50		Vapor Density (Air=1): 4.54 Vapor Pressure: 58 (mmHg@20C)																	
Fire Hazard NFPA rating: 2 HMIS rating: 2		Reactivity Hazard NFPA rating: 0 HMIS rating: 0		Health Hazard		NFPA rating: 2 HMIS rating: 2																			
Flash Point(°F): 90 LEL(%): 8 UEL(%): 10.5 Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input checked="" type="checkbox"/> Foam <input type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid		Incompatibilities: <u>Strong caustics; alkalis; chemically active metals (such as barium, lithium, sodium, magnesium, titanium and beryllium)</u> DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive		Odor Threshold (ppm): 82 IDLH (ppm): 1000 <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source (ppm)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>OSHA PELs</td> <td>100</td> <td>NA</td> <td>200, 300*</td> </tr> <tr> <td>ACGIH TLVs</td> <td>50</td> <td>100</td> <td>NA</td> </tr> </tbody> </table> *5-Min peak in any two hours. Signs/Symptoms of Acute Exposure: <u>Irritation of eyes and skin; headache; vertigo; visual disturbance; fatigue; giddiness; tremor; sleepiness; nausea; vomiting; dermatitis</u> DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source (ppm)				OSHA PELs	100	NA	200, 300*	ACGIH TLVs	50	100	NA	Carcinogenic: OSHA: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> Not listed IARC: <input type="checkbox"/> Group 1 <input checked="" type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input type="checkbox"/> Known <input checked="" type="checkbox"/> Anticipated <input type="checkbox"/> Process <input type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input type="checkbox"/> A2 <input type="checkbox"/> A3 <input type="checkbox"/> A4 <input checked="" type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive			
	TWA	STEL	C																						
Source (ppm)																									
OSHA PELs	100	NA	200, 300*																						
ACGIH TLVs	50	100	NA																						
Air Monitoring																									
Type		Brand/Model No.			Calibration Method/Media																				
<input type="checkbox"/> Explosimeter		Gastech GX-82			Methane																				
<input checked="" type="checkbox"/> PID		MiniRAE			Isobutylene																				
<input checked="" type="checkbox"/> FID		Foxboro OVA			Methane																				
<input checked="" type="checkbox"/> Colorimetric Tubes		Drager/CH24401 (10-500ppm)			Check pump for leaks																				
<input type="checkbox"/> Chemical Monitor <input type="checkbox"/> Dust Monitor																									
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#1022			Calibrate pump w/ media																				
Protective Clothing																									
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North <input type="checkbox"/> Neoprene/Mapa <input type="checkbox"/> PVC/Ans.Ed. <input type="checkbox"/> Butyl/North		<input type="checkbox"/> Viton/Best <input type="checkbox"/> Neoprene/Ans.Ed. <input type="checkbox"/> PVC/BestHustler <input type="checkbox"/> PVA/Ans.Ed.		<input checked="" type="checkbox"/> Silvershield/North <input type="checkbox"/> Neoprene/BestUltraflex <input type="checkbox"/> Nitrile/LabSafe. <input type="checkbox"/> Other		<input checked="" type="checkbox"/> 4H/Safety <input type="checkbox"/> Neoprene/BestNeo.(30min) <input type="checkbox"/> Nitrile/Ans.Ed.																	
Suit Type (Breakthrough >1hr unless noted):		<input type="checkbox"/> Tyvek <input type="checkbox"/> Tyvek QC		<input type="checkbox"/> Tyvek/Saranex <input type="checkbox"/> Tychem7500		<input checked="" type="checkbox"/> Tychem 9400		<input type="checkbox"/> Other																	
Respiratory Protection																									
<input type="checkbox"/> Air Purifying		<input checked="" type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: NA			Full face: NA																		
Notes: Prepared by: Sherry Hall																									
Date: 16 January 1997, Rev. 30 January 2002																									

CONTAMINANT FACT SHEET - XYLENE (MIXED ISOMERS)

CAS Number: varies w/ isomer Synonyms: o-xylene, p-xylene, m-xylene		Molecular Weight: 106.2 Physical State: Liquid	Color: Colorless Odor: Aromatic	Ionization Potential (eV): 8.44 Henry's Constant: 0.17	Vapor Density (Air=1): 3.66 Vapor Pressure: 7 (mmHg@20°C)																
Fire Hazard NFPA rating: 3 HMIS rating: NE	Reactivity Hazard NFPA rating: 0 HMIS rating: 0	Health Hazard NFPA rating: 2 HMIS rating: 2																			
Flash Point(°F): 81 LEL(%): 0.9 UEL(%): 6.7 Fire Extinguishing Media: <input checked="" type="checkbox"/> Dry Chemical <input checked="" type="checkbox"/> Foam <input type="checkbox"/> Water Spray <input checked="" type="checkbox"/> CO ₂ Fire Extinguisher: <input type="checkbox"/> Class A <input type="checkbox"/> Class B <input type="checkbox"/> Class C <input type="checkbox"/> Class D <input checked="" type="checkbox"/> Class A/B/C DOT: <input checked="" type="checkbox"/> Flammable Liquid <input type="checkbox"/> Combustible Liquid	Incompatibilities: Strong oxidizers; strong acids DOT: <input type="checkbox"/> Oxidizer <input type="checkbox"/> Water Reactive	Odor Threshold (ppm): 20 IDLH (ppm): 900 <table border="1" style="width:100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th></th> <th>TWA</th> <th>STEL</th> <th>C</th> </tr> </thead> <tbody> <tr> <td>Source (ppm)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>OSHA PELs</td> <td>100</td> <td>NA</td> <td>NA</td> </tr> <tr> <td>ACGIH TLVs</td> <td>100</td> <td>150</td> <td>NA</td> </tr> </tbody> </table> Signs/Symptoms of Acute Exposure: Irritation of eyes, nose, & throat; dizziness; excitement; drowsiness; incoherence; staggering gait; cornea vacuolization; anorexia; nausea; vomiting; abdominal pain; dermatitis DOT: <input type="checkbox"/> Poison			TWA	STEL	C	Source (ppm)				OSHA PELs	100	NA	NA	ACGIH TLVs	100	150	NA	Carcinogenic: OSHA: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> Not listed IARC: <input type="checkbox"/> Group 1 <input type="checkbox"/> Group 2A <input type="checkbox"/> Group 2B <input checked="" type="checkbox"/> Group 3 <input type="checkbox"/> Group 4 <input type="checkbox"/> Not listed NTP: <input type="checkbox"/> Known <input type="checkbox"/> Anticipated <input type="checkbox"/> Process <input checked="" type="checkbox"/> Not listed ACGIH: <input type="checkbox"/> A1 <input type="checkbox"/> A2 <input type="checkbox"/> A3 <input checked="" type="checkbox"/> A4 <input type="checkbox"/> A5 <input type="checkbox"/> Not listed Skin Absorbable: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No Skin Corrosive: <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No DOT: <input type="checkbox"/> Corrosive	
	TWA	STEL	C																		
Source (ppm)																					
OSHA PELs	100	NA	NA																		
ACGIH TLVs	100	150	NA																		
Air Monitoring																					
Type		Brand/Model No.		Calibration Method/Media																	
<input checked="" type="checkbox"/> Explosimeter		GasTech GX-82		Methane																	
<input checked="" type="checkbox"/> PID		MiniRAE		Isobutylene																	
<input checked="" type="checkbox"/> FID		Foxboro OVA		Methane																	
<input checked="" type="checkbox"/> Colorimetric Tubes		Drager/6733161(10-400ppm)		Check pump for leaks																	
<input type="checkbox"/> Chemical Monitor <input type="checkbox"/> Dust Monitor																					
<input checked="" type="checkbox"/> Collection Medium/Sampling Pump		Gilian Pump/NIOSH#1501		Calibrate pump w/ media																	
Protective Clothing																					
Glove Type/Brand (Breakthrough >2 hrs unless noted):		<input checked="" type="checkbox"/> Viton/North <input type="checkbox"/> Neoprene/Mapa <input type="checkbox"/> PVC/Ans.Ed. <input type="checkbox"/> Butyl/North	<input type="checkbox"/> Viton/Best <input type="checkbox"/> Neoprene/Ans.Ed. <input type="checkbox"/> PVC/BestHustler <input type="checkbox"/> PVA/Ans.Ed.	<input checked="" type="checkbox"/> Silvershield/North <input type="checkbox"/> Neoprene/BestUltraflex <input checked="" type="checkbox"/> Nitrile/LabSafe.(92min) <input type="checkbox"/> Other	<input checked="" type="checkbox"/> 411/Safety <input checked="" type="checkbox"/> Neoprene/BestNeo.(37min) <input checked="" type="checkbox"/> Nitrile/Ans.Ed. (75min)																
Suit Type (Breakthrough >1hr unless noted):		<input type="checkbox"/> Tyvek <input type="checkbox"/> Tyvek QC <input type="checkbox"/> Tyvek/Saranex <input type="checkbox"/> Tychem7500	<input checked="" type="checkbox"/> Tychem 9400	<input checked="" type="checkbox"/> Tychem 10,000 <input type="checkbox"/> Other																	
Respiratory Protection																					
<input checked="" type="checkbox"/> Air Purifying		<input type="checkbox"/> Air Supplied Only		Maximum Use Concentration (ppm): Half mask: 900 Full face: 900																	
Notes: The most conservative values were chosen if values were given in the literature for all isomers. Prepared by: Sherry Hall																					
Date: 16 January 1997, 31 January 2002																					

ATTACHMENT C

Appendix C

Hazard Mitigators Directory

<i>Included in HASP</i>	<i>Hazards</i>
<i>I. Chemical Hazards</i>	
<input type="checkbox"/>	Fire
<input checked="" type="checkbox"/>	Inhalation (Dust)
<input type="checkbox"/>	Permanganate Handling
<input checked="" type="checkbox"/>	Reactivity
<input checked="" type="checkbox"/>	Skin Absorption
<i>II. Physical Hazards</i>	
<input checked="" type="checkbox"/>	Boating
<input type="checkbox"/>	Chainsaw
<input checked="" type="checkbox"/>	Cold Stress
<input type="checkbox"/>	Compressed Gas Cylinder
<input type="checkbox"/>	Downhole Logging
<input checked="" type="checkbox"/>	Drilling (Including Indoor)
<input checked="" type="checkbox"/>	Drum and Container Handling
<input checked="" type="checkbox"/>	Electrocution
<input checked="" type="checkbox"/>	Excavation/Trenching
<input checked="" type="checkbox"/>	Eye Injury
<input type="checkbox"/>	Fall Protection
<input checked="" type="checkbox"/>	Flash Flood
<input checked="" type="checkbox"/>	Hand/Foot Injury
<input checked="" type="checkbox"/>	Heat Stress
<input checked="" type="checkbox"/>	Heavy Equipment
<input type="checkbox"/>	Helicopter
<input checked="" type="checkbox"/>	Lifting Heavy Loads
<input type="checkbox"/>	Lockout/Tagout
<input checked="" type="checkbox"/>	Noise
<input type="checkbox"/>	Nuclear Gauge Radiation Exposure
<input checked="" type="checkbox"/>	Portable Power/Hand Tool
<input checked="" type="checkbox"/>	Slips, Trips and Falls
<input type="checkbox"/>	Thoroughfares
<input checked="" type="checkbox"/>	Welding and Cutting
<input type="checkbox"/>	Other
<i>III. Biological Hazards</i>	
<input checked="" type="checkbox"/>	Allergic Reaction to Poisonous Plants
<input checked="" type="checkbox"/>	Bees
<input type="checkbox"/>	Dog
<input checked="" type="checkbox"/>	Insect/Vermin/Snake Bites
<input type="checkbox"/>	Medical Waste
<input type="checkbox"/>	Mountain Lions
<input type="checkbox"/>	Other

HAZARD MITIGATORS – *INHALATION*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Be aware that the lungs are extremely vulnerable to chemical agents. Even substances that do not directly affect the lungs may pass through lung tissue into the bloodstream, where they are transported to other vulnerable areas of the body.
- Know the odor and odor threshold of the chemicals of concern. Some toxic chemicals present in the atmosphere may not be detected by human senses (i.e., they may be odorless and colorless, and their toxic effects may not produce any immediate symptoms).
- Use engineering controls to reduce dust (e.g. dust suppression techniques) and vapor concentrations (e.g. ventilation).
- Wear respiratory protection as indicated by air monitoring results and/or as required by the Health and Safety Plan.

HAZARD MITIGATORS - *REACTIVITY*

Applies to Task: ☐ ① ☐ ② ☐ ③ ☐ ④ ☐ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Be aware of the chemical properties (e.g., air reactive, water reactive) of the contaminants of concern at the site.
- Be aware of incompatibilities between contaminants of concern at the site.
- Be aware of incompatibilities between chemicals that you bring onto the job site (e.g., decontamination solutions, sample preservatives, etc.) and the chemicals of concern at the site.
- Do not store incompatible chemicals together.
- Be aware of the reactivity of chemicals with storage containers, hoses, gloves etc.
- Make sure your spill containment and fire fighting materials are compatible with your chemicals of concern and chemicals stored on site.
- Be aware of first aid treatments required if exposed to chemicals of concern at the site or chemicals brought to the site.
- Use segregation techniques when performing drum handling activities.

HAZARD MITIGATORS - *SKIN ABSORPTION*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Be aware of chemicals of concern that can directly injure (corrode, burn, dehydrate) the skin or that can be absorbed into the bloodstream and subsequently transported to other organs from dust, liquid or vapor sources.
- Know that skin absorption is enhanced by abrasions, cuts, heat, and moisture.
- Do not wear contact lenses in contaminated atmospheres (since they may trap chemicals against the eye surface). The eye is particularly vulnerable because airborne chemicals can dissolve in its moist surface and be carried to the rest of the body through the bloodstream (capillaries are very close to the surface of the eye).
- Keep hands away from face.
- Minimize contact with liquid and solid chemicals.
- Wear protective clothing (e.g., suits and gloves) as specified by the Site Specific Health and Safety Plan.

HAZARD MITIGATORS - *BOATING*

Applies to Task: ☐ ① ☐ ② ☐ ③ ☒ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Review safe boating practices and procedures prior to undertaking tasks requiring the use of boats or other watercraft. Ensure that employees are familiar with the geographical area and know how to read boating signs and notices.
- Utilization of the buddy system during boating activities is mandatory.
- Secure all items on board.
- Coast Guard approved life jackets shall be worn at all times.
- Do not overload the boat or exceed its seating capacity. Distribute loads evenly.
- Ensure that the following items are maintained in working order on the boat at all times: oars or paddles, first aid kit, rope, anchor, life jackets, throwing cushion or ring as legally required, waterproof flashlights and/or floodlights, communication device (such as radio or cell phone), extra fuel, air horn, fire extinguisher, flares or signaling device, whistle and emergency spill kits.
- Comply with federal, state and local boating regulations and procedures.
- Cover slippery surfaces with waterproof traction tape. Limit standing and/or shifting of weight towards the outer edges of the boat. Never jump into or out of a moving boat or raft.
- Pre-planning is essential. Tell at least one person remaining behind about your plans prior to undertaking any boating activities, including departure time and estimated time of return. Log activities into an approved logbook, if necessary. If using a logbook, ensure that it is readily visible and accessible. Secure it to prevent it from being lost or removed. Make sure a writing instrument is attached to the logbook at all times.
- Be aware of weather conditions. Check weather reports prior to, and during, boating activities. Be prepared to turn back to shore at any indication of inclement weather.
- Have a “kill switch” on the boat for immediate shut off of power in case someone falls overboard.
- During motor operation remain in the boat at all times, except during emergency situations.

HAZARD MITIGATORS - *BOATING*

Applies to Task: ☐ ① ☐ ② ☐ ③ ☒ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Be aware that navigational warnings may be required on waters if the boat will be stationary in a high-activity area.
- Be aware that personal protective clothing can severely limit swimming ability and affect boat stability.
- If on open water without protection from sunlight, use sun protection. Wear sunglasses to protect your eyes from glare. Attach a neck cord to the sunglasses to prevent loss.
- Carry a waterproof container onboard to hold the following items: sunscreen, insect repellent, sunglasses, emergency contact information and communication equipment.
- Everyone should carry a personal; waterproof ID that includes emergency contact information.
- Use extra caution in areas where snake or alligators may be present
- Be aware of your surroundings at all times. Stay alert!
- Vessels must be registered as required by applicable state laws to operate a watercraft.
- When conducting electrofishing activity, the remote circuit interrupter switch must be used.

HAZARD MITIGATORS – COLD STRESS

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Work in pairs to keep an eye on each other and watch for signs of cold stress.
- Wear layers of loose fitting clothing, including insulated coveralls, head covering, gloves and boots.
- Minimize wind chill effects by wearing a wind resistant outer shell.
- Minimize lengthy periods of outdoor activity. This may require additional shifts and taking frequent breaks to warm up.
- Provide warm shelter.
- Remain hydrated. There is a tendency not to drink as many fluids when temperature is cold.
- Be aware of the symptoms of cold stress and appropriate first aid measures. Because of the considerable danger to personnel, outdoor work should be suspended if the ambient temperature drops below 0°F or if the wind chill factor drops below -29°F.

Signs and symptoms:

Mild hypothermia

Shivering, lack of coordination, stumbling, fumbling hands, slurred speech, memory loss, pale and cold skin.

Moderate hypothermia

Shivering stops, unable to walk or stand, confused and irrational.

Severe hypothermia

Severe muscle stiffness, very sleepy or unconscious, ice cold skin.

Treatment:

Mild hypothermia

Move to warm area, stay active, remove wet clothes and replace with dry clothes or blankets, cover the head, drink warm (not hot) sugary drink.

HAZARD MITIGATORS – COLD STRESS

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

Moderate hypothermia

Call for an ambulance, cover all extremities completely, Place very warm objects, such as hot packs or water bottles on the victim's head, neck, chest and groin and follow treatments for mild hypothermia.

Severe hypothermia

Call for an ambulance, treat the victim very gently, cover all extremities completely.

HAZARD MITIGATORS –DRILLING (INCLUDING INDOOR)

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- All members of the drilling crews shall be trained in the standard operating safety features and procedures to be utilized during operation, inspection, and maintenance of the equipment.
- Wear hard hats, steel toed boots, hearing protection and safety glasses at all times when performing drilling operations.
- Conduct a survey, prior to bringing drilling equipment to the job site, to identify overhead electrical hazards, potential subsurface hazards, and terrain hazard. Once on site, before drilling equipment is moved, the travel route shall again be visually surveyed for overhead and terrain hazards. Document possible hazards and communicate them to the drilling crew.
- Use only drilling equipment equipped with two easily-accessible emergency shutdown devices, one for the operator and one for the helper. Shutdown devices should be tested at the beginning of each day.
- Do not transport drilling equipment with the mast in the upward position.
- Extend outriggers per the manufacturer's specifications.
- Monitor weather conditions. Operations shall cease during electrical storms or when electrical storms are imminent.
- Wearing of loose clothing (e.g., open shirts, hooded sweatshirts, etc) is not permitted.
- When appropriate use auger guides on hard surfaces.
- Verbally alert employees and visually ensure employees are clear from dangerous parts of equipment prior to starting or engaging equipment.
- Channel the discharge of drilling fluids away from the work area to prevent the ponding of water.
- Use hoists only for their designed intent. Hoists shall not be loaded beyond their rated capacity. Steps shall be taken to prevent two-blocking of hoists (the condition when the lower load block or hook assembly comes in contact with the upper load block, or when the load block comes in contact with the boom tip).

HAZARD MITIGATORS –DRILLING (INCLUDING INDOOR)

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Follow the equipment manufacturer's procedures if ropes become caught in, or objects are pulled into a cathead.
- Do not run or rotate drill rods through rod slipping devices. No more than 5 feet of drill rod column shall be hoisted above the top of the drill mast. Drill rod tool joints shall not be made up, tightened, or loosened while the rod column is supported by a rod slipping device.
- Control dust using dust suppression techniques.
- Clean augers, drill casing, or drill rod only when the rotating mechanism is in neutral and the pipe is stationary is stopped.
- Cap and flag open boreholes; open excavations shall be barricaded.
- Keep all hand tools used during drilling operations clean and in good working condition.
- Check fire extinguishers and notify all onsite personnel to their whereabouts.
- Check cables for frays and hydraulic hoses for leaks daily.
- In situations where ambient water level may be above top of well screen, during well construction, ensure that well casing is vented to prevent air pressure build-up in blank casing above screen.

Indoor Drilling

- Conduct a survey, prior to bringing drilling equipment to the job site, to identify ceiling height, overhead hazards, potential subsurface hazards, terrain hazard, and building stability particularly during drilling activities. Identify sources of ventilation (including open doorways for cross ventilation and fans to assist in air flow). Once on site, before drilling equipment is moved, the travel route shall again be visually surveyed for overhead and terrain hazards and avenues of ventilation will be opened or turned on.
- Notify and/or evacuate all building occupants prior to start of drilling activities.
- All drilling rig exhaust will be redirected outdoors by tubing. The perimeter of the outdoor exhaust area shall be roped off a suitable distance to allow proper ventilation of exhaust.
- Monitor ambient oxygen percentage and carbon monoxide concentrations in the work zone, as well as entire indoor area, to prevent low oxygen or high carbon monoxide environments. Operations shall cease and the building will be evacuated if levels become dangerous.

HAZARD MITIGATORS – DRUM AND CONTAINER HANDLING

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Only trained personnel should open drums containing unknown materials.
- Bulging drums or containers are an indication of pressure build-up. Open all drums or bungs extremely slowly to determine the presence of vapors or pressure inside the drum. If the possibility of fire or explosion exists, a protective shield should be used and/or remote opening devices. Employees not directly involved with opening a container shall be kept a safe distance away.
- Use only drums and containers that meet the appropriate DOT, OSHA, and EPA regulations.
- Utilize drum/container handling equipment whenever possible. The equipment should have a sufficiently rated load capacity and should be able to operate smoothly on the available surface.
- Label and identify drums and containers when moved to the staging areas to safely identify and classify their contents. Segregate incompatible drums.
- Inspect the integrity of the drum container before moving. Any drum or container lacking integrity shall be placed within an over pack container.
- Staging areas require adequate escape routes. Staging area should provide secondary containment for all moved drums.
- Employees must be warned of the potential hazards associated with the contents of containers or drums prior to moving said containers or drums.
- Organize site operation to minimize the amount of drum or container movement. Have a clear view of the available pathway when moving drums. If needed, an additional person should be available to provide guidance.
- Never stand on drums or containers.
- Use non-sparking tools and appropriate grounding and bonding equipment.

HAZARD MITIGATORS – *DRUM AND CONTAINER HANDLING*

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Appropriate fire extinguishing equipment must be onsite at all times during drum handling.
- Spill control equipment shall be onsite in areas where spills ruptures or leaks may occur.

HAZARD MITIGATORS - *ELECTROCUTION*

Applies to Task: ☐ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Install adequate warning signs and barriers (in plain sight) in all areas where hazardous electrical facilities exist.
- Use only heavy duty electrical cords that are not subjected to excessive bending, stretching, or kicking. All cords and wires shall be frequently inspected for signs of defects. Damaged or frayed electrical wires, cords, and plugs shall be immediately replaced by a qualified electrician or other properly trained personnel.
- Equip all portable extension cords with a non-conducting plug and/or another socket shell. All electrical cords shall be equipped with three-blade grounding type plugs.
- Do not permit overloading of electrical circuits at anytime. The replacement of fuses or circuit breakers with makeshift materials or over-capacity fuses is strictly prohibited.
- A minimum clearance of 20 feet (radius) will be maintained between heavy equipment (i.e., drill rig) and any overhead power lines, regardless of voltage.
- Before subsurface work, a utilities search for underground lines will occur and will be documented (if within 3 feet of marked underground utility, hand digging is required).
- Installation and maintenance of electrical facilities or equipment must only be performed by qualified and properly authorized personnel or electrical subcontractors. Apprentice personnel permitted to work on electrical equipment shall be under the supervision of a fully qualified electrician.
- Follow the company Lock-out/Tag-out procedures when applicable. Electrical equipment and lines shall always be considered “energized” until proven “de-energized”. Before beginning work, each electrical circuit shall be inspected, tested, and where possible, isolated from the power source. Extreme care shall be exercised as wires designed to operate at ground potential may become energized by faulty or inadequate connections.
- Do not wear rings, watches or metallic objects that could act as conductors when working with electrical circuits.
- Do not use metal ladders and uninsulated tools while working with electrical circuits and equipment.
- Protect electrical wires with suitable protective conduits or devices where they are exposed to possible damage.
- Connect grounding devices to a ground before contacting any conductor of a circuit.

HAZARD MITIGATORS - *ELECTROCUTION*

Applies to Task: ☐ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

When grounding devices are removed, they shall be disconnected from the circuit before being disconnected from ground.

- The type of circuit shall determine the type of protective equipment required. Rubber gloves, sleeves, blankets, mats, and insulated platforms shall be used as required. Questions regarding PPE should be directed to the SHSO.
- Inspect all insulated protective equipment continuously for defects or damages. Any defective equipment shall be replaced before using.
- Establish and enforce testing schedules for insulation qualities for protective equipment. All users shall verify that equipment has been satisfactorily tested prior to use.
- Electricians shall be familiar with the National Electrical Code; state and local electric codes; OSHA standards, including 29 CFR 1926, Subpart K; and applicable sections of the National Fire Protection Association Codes.
- When working on energized circuits of 440 volts or higher, at least one qualified electrician and one other employee shall be present.
- Use only NEC approved grounding equipment as a ground for electrical equipment. Metal frames on electricity-powered equipment, electrical facilities, and transmission equipment shall be connected to the grounding system. Alternative grounding systems complying with applicable electrical codes may be used for temporary portable equipment.

HAZARD MITIGATORS - EXCAVATION/TRENCHING

Applies to Task: ☐ ① ☐ ② ☒ ③ ☐ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

Prior to Excavation

- Confirm that an OSHA competent person is available. An OSHA competent person is someone with enough training to identify soil types and other excavation hazards and authority to take prompt corrective actions.
- Check for the presence of underground and aboveground utilities before conducting any intrusive work. Support, protect or remove utility lines as appropriate.
- Implement the GeoSyntec Confined Space Entry Program if employees are to enter excavations or trenches of 4 feet deep or deeper (regardless of width).
- Remove or brace trees, boulders, etc., adjacent to the work area that could fall into the work area before intrusive begins.
- Underpin all nearby existing structures to ensure their stability before excavating below the level of the base of the footing of any foundation or retaining wall.

During Excavation

- Wear hard hats, safety boots and reflective vests.
- Use flagmen or warning devices for all mobile equipment using reverse and forward motion
- Adequately slope or shore all sides of excavations/trenches 5 feet or more in depth (depending on local regulations) before allowing anyone to enter them (see below).
- Store and retain all equipment/material and excavated soil/rock/waste (spoil(s)) at least 2 feet or more from the edge of the excavation/trench.
- Use diversion ditches or dikes to prevent water from entering an excavation, and to provide adequate drainage of the area adjacent to the excavation. Prevent water from accumulating in an excavation.
- Install substantial stop logs or barricades when mobile equipment is used or allowed adjacent to excavations.
- Provide a walkway or bridge with standard guardrails where employees or equipment are required or permitted to cross over excavations.

HAZARD MITIGATORS - EXCAVATION/TRENCHING

Applies to Task: ☐ ① ☐ ② ☒ ③ ☐ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Ladders used for ingress/egress should extend a minimum of 3' above ground surface, be secured, and be located so as to require no more than 25 feet of lateral travel for workers in the trench or excavation.
- Avoid standing on top of trench/excavation while personnel are below, in the trench.
- Examine all excavation work areas and faces for unsafe conditions at least at the beginning of each shift and especially after blasting, a rain, a freeze or a thaw. If unsafe conditions are found, all work in that immediate area shall cease until the necessary

If it is necessary to place or operate trucks, materials or other heavy objects on a level above and near an excavation, pile, shore, and/or brace sides of excavations to resist the extra pressure due to such superimposed loads.

Shoring an Excavation

- Place cross braces or trench jacks in a true horizontal position, space vertically and secure to prevent sliding, falling or kickouts.
- Use portable trench boxes or sliding trench shields, if needed, in place of a shoring system or sloping.
- Support systems shall be planned and designed by a qualified professional engineer when the excavation is in excess of 20 feet in depth, adjacent to structures or improvement, or subject to vibration or ground water.
- Removal and backfilling of trench supports must slowly progress together from the bottom of the trench. Jacks or braces shall be released slowly and in unstable soil, ropes shall be used to pull out the jacks or braces from above after employees have cleared the trench.
- Stability of an excavation left open for a long period of time(i.e. more than a few days) should be evaluated by a professional engineer to assess if slopes, bracing measures, etc. need to be modified.
- Start backfilling trench before removing braces in case of Type C soils.
- Put up barricades – flagging tape, fencing to prevent falls into the excavation.
- Cover or secure trench/excavation if left open overnight.

HAZARD MITIGATORS - EXCAVATION/TRENCHING

Applies to Task: ☐ ① ☐ ② ☒ ③ ☐ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

Sloping an excavation

- Excavate to at least the OSHA minimum required angle ratio (see Table ET-1) according to soil classification identified except for areas where solid rock allows for line drilling or pre-splitting.
- Flatten the angle of repose when an excavation has water conditions, silty materials, loose boulders, and areas where erosion, deep frost action and slide planes appear

Soil Classification	Soil Classification Description	OSHA Minimum Requirements For Side Slopes
Soil Type A	Most stable: clay, silty clay and hardpan (resists penetration)	.75:1 (for one foot vertical rise, the trench wall must be cut back $\frac{3}{4}$ ')
Soil Type B	Medium stability: silt, sandy loam, medium clay and unstable dry rock	1:1 (each step has an equal horizontal and vertical rise; only cohesive Type B soils may be benched)
Soil Type C	Least stable: gravel, loamy sand, soft clay, submerged soil or dense, heavy unstable rock	1.5:1 (trench wall must be cut back 1-1/2' for 1' vertical rise; type C soil is not benched)

HAZARD MITIGATORS - EYE INJURY

Applies to Task: ☒ ①

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- Wear appropriate eye protection according to the task at hand.

HAZARD	TYPE OF PROTECTION
Impact	Safety glasses with side shield or vented safety goggles
Heat (Sparks)	Vented safety goggles or safety glasses with a face shield
Chemical	Hooded vented safety goggles or full-face respirator (if mild chemicals then safety glasses with side shield is acceptable)
Light Radiation	Tinted/reflective safety glasses or tinted/reflective face shield
Dust	Hooded vented safety goggles

- Apply anti-fog product to lens not previously treated.
- Minimize the amount of vapor or particulate matter generated, if possible.
- Avoid touching the face and eyes.
- Flush eyes with water for at least 15 minutes if chemicals do get into the eyes. If condition persists, seek medical attention.
- If dust or foreign objects are in your eyes, do not rub your eyes.
- If an object becomes embedded in the eye, do not attempt to remove. Lightly bandage your eyes, or both eyes, if possible and immediately seek medical attention.
- Do not wear contact lenses if chemical or dust hazard is present (e.g. decontamination or preservation chemicals used during sampling).
- Provide on-site training to workers before tasks at hand.

HAZARD MITIGATORS - *EYE INJURY*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- If visitors enter area, stop work until they are properly protected.

HAZARD MITIGATORS – FLASH FLOOD

Applies to Tasks: ☐ ① ☐ ② ☐ ③ ☒ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Be familiar of regional or local flash flood history in your work area.
- Be aware if your work area is in a floodplain, and if it is above or below flood stage water level.
- If available, review Flood Insurance Rate Maps (FIRMS).
- Always be aware of the latest weather forecast in your area, especially if your work site is prone to flash flooding.
- In the event of the heavy rain or steady rainfall during work, stop work immediately and head for higher grounds.

Once the Flood Arrives

- Don't drive through a flooded area. If you come upon a flooded road, turn around and go another way. More people drown in their cars than anywhere else.
- If your car stalls, abandon it immediately and climb to higher ground. Many deaths have resulted from attempts to move stalled vehicles.
- Don't walk through flooded areas. As little as six inches of moving water can knock you off your feet.
- Stay away from downed power lines and electrical wires. Electrocution is another major source of deaths in floods. Electric current passes easily through water.
- Look out for animals - especially snakes. Animals lose their homes in floods, too. They may seek shelter in yours.
- If the waters start to rise within your work area before you have evacuated, retreat to high ground such as cars, trucks, and field equipment.
- Take dry clothing, a flashlight and a portable radio with you. Then wait for help.
- Don't try to swim to safety; wait for rescuers to come to you.
- If outdoors, climb to high ground and stay there.

HAZARD MITIGATORS - *HAND/FOOT INJURY*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Wear protective gloves as required in the Health and Safety Plan. Gloves should be chosen to suit the work being performed (e.g., chemical resistant gloves will be worn when handling chemicals or sampling for suspected chemicals).
- Steel-toed/steel-shanked safety boots must be worn whenever working around heavy objects (or as required by the HASP). Insulated and/or waterproof boots may also be warranted depending on weather conditions. Boots should be inspected periodically for signs of wear (e.g., cracks in rubber or along soles) and replaced as required.
- Durable footwear which provides adequate ankle support should be worn when working in rugged terrain.
- Use proper lifting techniques to avoid dropping heavy loads on hands and feet (refer to lifting heavy loads hazard mitigator)
- Be aware of moving machinery and heavy equipment in the work area and tuck away any loose clothing.

HAZARD MITIGATORS – HEAT STRESS

Applies to Task: ☒ ①

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Prevention:

- Drink plenty of hydrating fluids, such as Gatorade® or water. In high heat, a minimum of one gallon per day should be consumed. Fluid should be consumed frequently. Don't wait until thirsty.
- Provide cooling devices, when necessary, to aid natural body heat exchange during prolonged work or severe heat exposure. Devices include field showers, hose-down areas, shade umbrellas/tents, wide-brim hats, and cooling jackets, vests, or suits.
- If amenable to work conditions, wear light-colored, loose fitting, "breathable" clothing.
- Avoid prolonged periods of exposure. Take breaks as necessary. Higher heat exposure requires more frequent breaks.
- Be able to recognize the signs, symptoms and how to treat for heat stress. Signs, symptoms and treatment are listed below.

Signs and Symptoms:

- Mild heat stress - Decreased energy, slight loss of appetite, nausea, lightheadedness.
- Moderate heat stress - heavy sweating, thirst, faintness, headache, confusion.
- Severe heat stress (heat stroke) - Throbbing headache, confusion, irritability, rapid heartbeat, difficulty breathing, dry skin (no sweating), vomiting, diarrhea.

Treatment:

- Mild and Moderate heat stress - Take to cool place, drink cool (not cold) fluids, remove excess clothing, rest.
- Severe heat stress - Call 911 for an ambulance and get to a cool place, remove excess clothing and rest.
- Adjust work and rest schedules as needed. Establish a work regimen that will provide adequate rest periods for cooling down. This may require additional shifts of workers.
- Provide shelter or shaded areas (77° F is best) to protect personnel during rest periods.
- Maintain worker's body fluids at normal levels to ensure that the cardiovascular system functions adequately. Daily fluid intake must equal the approximate amount of water lost in

HAZARD MITIGATORS – *HEAT STRESS*

Applies to Task: ☒ ①

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sweat. Workers are encouraged to drink more than the amount required to satisfy thirst (recommend water and sport drinks, not coffee or soda), because thirst is not an adequate indicator of adequate salt and fluid replacement.

- Remove impermeable protective garments during rest periods.
- Do not assign other tasks to personnel during rest periods.

HAZARD MITIGATORS – *HEAVY EQUIPMENT*

Applies to Task: ☐ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

Working around Heavy Equipment

- Yield to heavy equipment.
- Listen for warning signals on heavy equipment.
- Perform a visual inspection and walk around parked heavy equipment before moving to assure that equipment is in good condition and that there are no personnel on the ground that could be injured or objects that could be damaged by vehicle movement.
- Wear hearing protection if required.
- Wear traffic vests for increased visibility.
- Maintain eye contact with the heavy equipment operator when working near equipment.
- Be aware of changes in sound of equipment which may indicate a change in direction or activity.

Heavy Equipment Operators

- Use hand rails and footholds when mounting and dismounting equipment,
- Follow appropriate equipment startup procedures. Brakes, steering, clutches and controls shall be tested.
- Pay attention to workers on the ground who may be in the path and provide warning prior to moving the equipment.
- Permit no one to ride on, or in, heavy equipment. This includes any portion of a backhoe, bulldozer, forklift or the back of a pickup truck, except in locations specifically designed for passenger use and approved by the SHSO.
- Keep haulage vehicles under positive control at all times while operating. Vehicles shall be kept in gear when descending grades.
- Do not use heavy equipment on slopes with steepness exceeding 3H:1V unless operations are consistent with manufacturer's recommendations (if the Owner's Manual is not with the equipment or does not specify slope operating procedures, see the SHSO).

HAZARD MITIGATORS – HEAVY EQUIPMENT

Applies to Task: ☐ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Operate equipment with booms, blades, buckets, beds, etc., lowered or in a stable position while on slopes. Safety cables tethered to appropriate anchors shall be used for equipment working on steep slopes, where appropriate. The use of cables and anchors must be approved by the SHSO.
- Suspend in slings or support by hoists or jacks heavy equipment in need of repair. The equipment must also be blocked or cribbed before workers are permitted to work underneath. Working under heavy equipment can pose a crushing hazard.
- Shut off motors, do not allow smoking, and use proper dispensing equipment when refueling gasoline-operated equipment to prevent fire hazards.
- Lower hydraulic systems (e.g., blades, rippers, etc.) to the ground, set brakes, and shut down equipment if malfunction occurs which impairs the ability to control a piece of equipment.
- Use rollover protection and seat belts.

HAZARD MITIGATORS – *LIFTING HEAVY LOADS*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Proper lifting techniques include:
 - *Feet* - Feet should be parted, with one foot alongside the object being lifted and one behind. Feet should be comfortably spread to give greater stability. The rear foot should be in position for the upward thrust of the lift.
 - *Back* - Use the sit-down position and keep the back straight, but remember that “straight” does not mean “vertical”. A straight back keeps the spine, back muscles, and organs of the body in correct alignment. It minimizes the compression of the abdomen that can cause a hernia.
 - *Arms and Elbows* - The load should be drawn close to the body, and the arms and elbows should be tucked in. When the arms are held away from the body, they lose much of their strength and power. Keeping the arms tucked in also helps keep body weight centered.
 - *Palm* - The palm grip is one of the most important elements of lifting. The fingers and the hand are extended around the object to be lifted. Use the full palm; fingers alone have very little power.
 - *Chin* - Tuck in the chin so the neck and head continue the straight back line. Keep the spine straight and firm.
 - *Body Weight* - Position the body so its weight is centered over the feet. This provides a more powerful line of thrust and assures better balance. Start the lift with a thrust of the rear foot. Shift hand positions so the object can be boosted after knees are bent. Straighten knees as object is lifted or shifted to the shoulders. To change direction, lift the object to a carrying position, and turn the entire body, including the feet. Do not twist your body. In repetitive work, both the person and the material should be positioned so that the worker will not have to twist his body when moving the material. If the object is too heavy to be handled by one person, get help.
- Limit continuous lifting of weights to 50 pounds or the maximum allowed by the client whichever is less. Lifts of heavier weights are permitted on an interim basis. Help shall be obtained for lifting of loads greater than 50 pounds or the maximum allowed by the client whichever is less. Mechanical equipment should be used on heavy materials when possible. If mechanical assistance is not available, adequate manpower to maintain the 50-pound limit per employee will be required.

HAZARD MITIGATORS – *LIFTING HEAVY LOADS*

Applies to Task: ☒ ①

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- Do not lift more weight than can be handled comfortably, regardless of load weight. If necessary, help should be requested to lift a load so that the lifting is comfortable.
- Use drum dollies when moving drums or barrels.
- Inspect objects for grease or slippery substances before they are lifted to ensure that the object will not slip.
- Do not carry long, bulky or heavy objects without first verifying that the way is clear and that vision is unobstructed. This ensures that other persons or objects will not be struck by the load.
- Do not carry loads that cannot be seen over or around.
- Exercise caution when lifting above the chest level.
- Make sure workers are physically suited for the job before assigning jobs requiring heavy and/or frequent lifting. A person's lifting ability is not necessarily indicated by his height or weight.
- Before lifting an object, consideration should be given to how the object will be set down without pinching or crushing hands or fingers. For example, to place an object on a bench or table, the object should be set on the edge and pushed far enough onto the support so it will not fall. The object can then be released gradually as it is set down, and pushed in place with the hands and body from in front of the object.
- When two or more people are handling the same object, one should "call the signals". All the persons on the lift should know who this person is and should warn him if anyone in the crew is about to relax his grip.

HAZARD MITIGATORS - *NOISE*

Applies to Task: ☐ ①

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- Wear hearing protection in areas with constant or loud noise.
- Know the effects of noise, including:
 - Workers being startled, annoyed, or distracted.
 - Physical damage to the ear, pain, and temporary and/or permanent hearing loss.
 - Communication interference that may increase potential hazards due to the inability to warn of danger and proper safety precautions to be taken.
- Implement the company Hearing Conservation Program when noise exposures equal or exceed an 8-hour, time-weighted average (TWA) sound level of 85 decibels on the A-weighted scale (dBA).
- Utilize feasible administrative or engineering controls if workers are subjected to noise exceeding an 8-hour TWA sound level of 90 dBA.

HAZARD MITIGATORS - *PORTABLE POWER/HAND TOOLS*

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Read instruction manual for the safe operation of any portable power tool.
- Route cords, hoses, and cables supplying power to portable power tools to prevent tripping hazards or contact with equipment or machinery.
- Avoid abusing the power supply lines of portable equipment. Excessive scraping, kicking, stretching, and exposure to grease and oils will damage lines or cause them to fail prematurely, and possibly injure the operator or fellow workers.
- Inspect cords, hoses, and cables for wear or deterioration. Defective power supply lines shall not be used.
- Do not use electrically powered tools near flammable materials or explosive atmosphere, unless they are of the explosion-proof type meeting the National Electrical Code for potentially explosive work areas. Employees operating the equipment should be aware of sparks and or metal fragments when using this equipment.
- Ground-check portable electric power tools with metal cases initially and quarterly. At no time will electrical power equipment be operated without proper grounding. All electrical cords and cables, including extension cords, shall include a third wire ground.
- Prohibit operations of electric tools in wet or damp areas except in unusual emergency circumstances. When operation is required in wet or damp conditions, extreme care will be exercised to ensure effective grounding of equipment and proper use of protective gear.
- Size cords adequately for length and the electrical demand of the tool. Otherwise, they may cause a fire hazard.
- Limit use of tools to the purpose for which the tool is intended (e.g., wrenches will not be used as hammers). Defective tools (e.g., with mushroomed heads or split or defective handles) shall not be used.
- Protect tools from corrosion damage.

HAZARD MITIGATORS - *PORTABLE POWER/HAND TOOLS*

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Keep tools free of accumulated dirt and unnecessary oil or grease. Moving and adjustable parts shall be lubricated frequently to prevent wear and misalignment.
- Replace or repair damaged or worn tools promptly. Temporary or makeshift repairs are prohibited. At the discretion of the supervisor, discard all tools that cannot be repaired safely. Supervisors shall decide when to discard a tool.
- Store tools in suitable boxes or containers. Loose tools shall not be stored on ledges or where they might fall. Tools shall be picked up when a job is completed and not be allowed to accumulate in the work area. Store all tools in a safe place.
- Do not use conducting (i.e., metal) tools around electrical facilities. Insulated tools, approved for electrical work, shall be tested frequently for proper insulation.
- Select the correct size and type of wrench for each job. Wrench handles shall not be extended with a pipe or cheater because the jaws will spread.
- Repair mushroomed punch, drift and chisel heads. Mushroomed heads represent crystallized metal that will break and fly off when struck.
- Wear eye protection at all times and ear protection when there is exposure to excessive noise.

HAZARD MITIGATORS – *SLIPS, TRIPS AND FALLS*

Applies to Task: ☒ ①

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- Wear the proper foot wear and clothing for the task at hand.
- Pay attention to the work environment and become aware of all equipment and vehicles active onsite and use caution when moving about.
- Use caution when walking on sloped areas (especially geosynthetics), particularly when moisture is present. Use caution when walking on soft or uneven surfaces; e.g., marsh areas. Watch for icy conditions in cold weather.
- Follow the established designated safe paths for travel and keep these areas free from debris. Avoid steep or slippery slopes and paths near operation vehicles and equipment.
- Follow good housekeeping procedures. Never assume that someone else will clean up a spill or put away an object.
- Remove or clearly mark objects that pose tripping hazards.
- Prevent water accumulation where practicable.
- Cables and/or wiring should be taped down, when possible. Locate cables and/or wiring out of the commonly used areas.
- Mark or repair any opening or hole in the floor.
- Carry objects in a manner that allows you to see in the area you are moving in. Do not carry objects that are too large or bulky. Do not carry more weight than you can balance and keep stable. Understand that PPE can reduce or limit your field of vision and mobility.
- Use the proper ladder for the task at hand and do not exceed the recommended height. Do not use the top two rungs of a ladder. Ensure a flat and stable footing for the placement of a ladder. Utilize the buddy system to help secure the ladder. When working over 6 ft., utilize fall prevention measures. Obey height and weight guidelines and/or rules.
- Use the handrail when using stairs. Be aware of stairway blockages.
- If conditions even slightly resemble an unsafe environment, do not make any assumptions that the integrity of a workplace is intact.

HAZARD MITIGATORS – *SLIPS, TRIPS AND FALLS*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Never jump over or into a trench or excavation.
- Walk, do not run.
- Maintain proper lighting so obstacles are clearly visible

HAZARD MITIGATORS - *WELDING / CUTTING*

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Reduce exposure to all welding emissions using engineering controls (ventilation) and safe work practices.
- All persons who weld or cut must be properly trained. Associated hazards include:
 - Thermal
 - Chemical fumes
 - Physical injury
 - Volatile combination of heat and gas
 - Radiation from unfiltered ultraviolet light
 - Electrical circuit
 - Gas leakage
 - Excessive noise
 - Poisoning
- Preventative fire measures include use of a welding blanket, removal or covering of flammable materials, and working a safe distance from flammable materials.
- Wear hearing protection, as required.
- Ensure that there is adequate lighting in the work area.
- Electrically insulate yourself. Wear rubber insulated boots, work on a well-insulated floor, use welding cables that are fully insulated and wear dry gloves when handling equipment.

HAZARD MITIGATORS - WELDING / CUTTING

Applies to Task: ☐ ① ☒ ② ☐ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

- Utilize the proper protective clothing and equipment (PPE), including:
 - Shield or helmet with filtered lens
 - Boots
 - Fire-resistant gloves
 - Leather spats
 - Leather apron
 - Felt skullcap or beret
 - Overalls
 - Hand shields
- Read the MSDS sheets for all hazardous substances with which you may come into contact prior to starting work.
- Never cut off the tops of drums that have contained flammable liquids or gases. Vapors left inside the drum may explode! If a drum that has held toxic or flammable substances must be cut, it should either be filled with water, or thoroughly cleaned of such substances by a specialist cleaning company, then ventilated and tested.
- Do not apply heat to drums that have held chemicals because it may cause them to produce poisonous gas.
- Never weld or grind near an empty drum. A single spark inside an empty drum can trigger an explosion. Keep torches, flames and sparks away from grinding and welding equipment.
- Under no circumstances should fittings of oxyacetylene equipment be allowed to become contaminated with grease or oil, which can ignite in the presence of pure oxygen.
- Have flashback arrestors fitted to all oxyacetylene equipment to overcome the danger of flashback.
- Store oxygen and gas separately. Store acetylene cylinders upright to prevent explosion. Always chain stored cylinders.

HAZARD MITIGATORS – ALLERGIC REACTION TO PLANTS

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Be able to recognize and identify poisonous plants indigenous to the site location (e.g., poison ivy, poison oak, poison sumac). For example, poison Ivy plants have three leaves arranged at the end of each stem. Two secondary leaves are attached opposite one another and directly to the stem at their base. The primary leaf is attached to the end of the stem. The leaves often, but NOT ALWAYS, have a shiny appearance. See photos below.



- Poison Ivy often appears as ground cover at the edge of wooded areas and along trails within fields and woods. It may also appear growing from a vine wrapped around trees.
- Avoid or remove poisonous plants where practicable. Wear appropriate protective clothing (e.g., gloves, long-sleeved shirts) as required.
- One can become sensitized (like a latex allergy) though immune for several years at the beginning.
- If you come in contact with the plant, the plant's oil will be transferred onto your skin and clothing. The best way to manage the oil is to wash skin with cool water and soap (preferably 5% tincture of green soap available at CVS). If soap and water is unavailable, thorough (2-3 minutes) rinsing with cold water may help (not warm...want to keep those pores closed!)
- The lag time between exposure and symptoms can be quite long like several days.
- If you are in the field, blot the area with an alcohol patch and follow by washing as soon as possible. Calamine lotion, Tecnu, yellow laundry soap, or Colloidal oatmeal (Aveeno ®) baths provide relief from itching and rashes. More Tecnu can be found at <http://www.teclabsinc.com/>.
- If you have to pass through heavy ivy growth, be sure to carefully handle your field cloths when you return. Your shoe laces will always get you if you are not careful. The oil can last on clothing for a few weeks, so wash frequently.
- For additional information, please see <http://poisonivy.aesir.com/>

HAZARD MITIGATORS – *BEES*

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

- Be aware of potential hive/nest locations, which may include culverts, drainage pipes, junk piles, or dense shrubbery.
- Advise the SHSO if you are allergic to bees prior to engaging in any field activities.
- Include the following controls:
 - Do not agitate bees or disrupt their hive/nest.
 - Keep the area quiet and calm.
 - Wear light-colored clothes.
 - Avoid wearing perfumes, hair spray, or scented lotions in the wilderness.
- If attacked:
 - Do not scream or wave arms.
 - Cover your face with your hands.
 - Run for shelter in a building or vehicle. Do not seek shelter in water.
 - Remove stingers as quickly as possible to lessen the amount of venom entering the body. Remove the stinger by raking your fingernail across it. Don't pinch or pull the stinger out. Put ice on the sting to reduce the swelling.
- Report any stings to the SHSO and seek first aid or emergency medical care immediately if stung several times.

HAZARD MITIGATORS – *INSECT/VERMIN/SNAKE BITES*

Applies to Task: ☒ ①

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- Be able to recognize insects/vermin/snakes indigenous to the site location and habitats. Learn the indigenous dangerous species (e.g., spiders, snakes, ticks) prior to entering the field and know the first aid treatments.
- Poisonous venomous snakes swim on top of the water, non-poisonous venomous snakes swim with only their heads above water.
- Advise the SHSO if you have allergies to any insects prior to engaging in any field activities.
- Include the following preventative measures as necessary: wear light-colored clothing, keep clothing buttoned, tuck pant legs into socks, keep shirt tails tucked in, boots, hoods, netting, gloves, masks, insect repellants or other personal protection.
- Snake bite kits are commercially available and should be carried by field personnel when working where poisonous snakes exist. In the case of a snake bite, keep the patient calm, restrict activity and immobilize the bite area (do not elevate), and immediately obtain medical attention.
- Report any bites or stings to the SHSO and seek medical attention immediately.

ATTACHMENT D

Attachment D

Air Monitoring Equipment / Frequency of Reading / Action Guidelines Per Task

Applies to Task: ☒ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

<input type="checkbox"/> Explosimeter Brand/Model No.: _____ Monitoring Frequency: _____ <hr/> <table style="width: 100%;"> <tr> <th style="text-align: left;">Source Reading (% LEL)</th> <th style="text-align: left;">Action</th> </tr> <tr> <td>1 to 10</td> <td>Continue with caution.</td> </tr> <tr> <td>Greater than 10</td> <td>Stop work. Evacuate the area. If upon return, concentration still exceeds 10% LEL, ventilate till LEL is back to zero.</td> </tr> </table> Note: _____	Source Reading (% LEL)	Action	1 to 10	Continue with caution.	Greater than 10	Stop work. Evacuate the area. If upon return, concentration still exceeds 10% LEL, ventilate till LEL is back to zero.	<input type="checkbox"/> Oxygen Meter Brand/Model No.: _____ Monitoring Frequency: _____ <hr/> <table style="width: 100%;"> <tr> <th style="text-align: left;">Source Reading (%)</th> <th style="text-align: left;">Action</th> </tr> <tr> <td>Less than 19.5</td> <td>Stop work. Evacuate the area. If upon return, concentration is still <19.5, Level B PPE must be acquired and worn by trained personnel.</td> </tr> <tr> <td>19.5 to 23.5</td> <td>Continue to work with caution.</td> </tr> <tr> <td>Greater than 23.5</td> <td>Stop work. Evacuate the area.</td> </tr> </table> Note: _____	Source Reading (%)	Action	Less than 19.5	Stop work. Evacuate the area. If upon return, concentration is still <19.5, Level B PPE must be acquired and worn by trained personnel.	19.5 to 23.5	Continue to work with caution.	Greater than 23.5	Stop work. Evacuate the area.	<input checked="" type="checkbox"/> Photoionization Detector Brand/Model No.: Thermo Model 580B Photoionization Detector (PID) (11.7eV) or equivalent PID with 11.7eV lamp. Monitoring Frequency: Continuous. <hr/> <table style="width: 100%;"> <tr> <th style="text-align: left;">Breathing Zone Reading</th> <th style="text-align: left;">Action</th> </tr> <tr> <td>0 to 2</td> <td>Level D PPE</td> </tr> <tr> <td>2 to 10</td> <td>Level C PPE</td> </tr> <tr> <td>Greater than >10</td> <td>Stop work. Evacuate the area. If upon return, levels still exceed >10 Level B PPE must be acquired and worn by trained personnel.</td> </tr> </table> Note: _____	Breathing Zone Reading	Action	0 to 2	Level D PPE	2 to 10	Level C PPE	Greater than >10	Stop work. Evacuate the area. If upon return, levels still exceed >10 Level B PPE must be acquired and worn by trained personnel.
Source Reading (% LEL)	Action																							
1 to 10	Continue with caution.																							
Greater than 10	Stop work. Evacuate the area. If upon return, concentration still exceeds 10% LEL, ventilate till LEL is back to zero.																							
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2 to 10	Level C PPE																							
Greater than >10	Stop work. Evacuate the area. If upon return, levels still exceed >10 Level B PPE must be acquired and worn by trained personnel.																							
<input type="checkbox"/> Flame Ionization Detector Brand/Model No.: _____ Monitoring Frequency: _____ <hr/> <table style="width: 100%;"> <tr> <th style="text-align: left;">Breathing Zone Reading (ppm)</th> <th style="text-align: left;">Action</th> </tr> <tr> <td>_____ to _____</td> <td>Level D PPE</td> </tr> <tr> <td>_____ to _____</td> <td>Level C PPE</td> </tr> <tr> <td>Greater than _____</td> <td>Stop work. Evacuate the area. If upon return, levels still exceed _____, Level B PPE must be acquired and worn by trained personnel.</td> </tr> </table> Note: _____	Breathing Zone Reading (ppm)	Action	_____ to _____	Level D PPE	_____ to _____	Level C PPE	Greater than _____	Stop work. Evacuate the area. If upon return, levels still exceed _____, Level B PPE must be acquired and worn by trained personnel.	<input type="checkbox"/> Chemical Detector Tube Brand/Model No.: _____ Monitoring Frequency: _____ <hr/> <table style="width: 100%;"> <tr> <th style="text-align: left;">Breathing Zone Reading (ppm)</th> <th style="text-align: left;">Action</th> </tr> <tr> <td>_____ to _____</td> <td>Level D PPE</td> </tr> <tr> <td>_____ to _____</td> <td>Level C PPE</td> </tr> <tr> <td>Greater than _____</td> <td>Stop work. Evacuate the area. If upon return, levels still exceed _____, Level B PPE must be acquired and worn by trained personnel.</td> </tr> </table> Note: _____	Breathing Zone Reading (ppm)	Action	_____ to _____	Level D PPE	_____ to _____	Level C PPE	Greater than _____	Stop work. Evacuate the area. If upon return, levels still exceed _____, Level B PPE must be acquired and worn by trained personnel.	<input checked="" type="checkbox"/> Other High-Volume (HV) Sampler with quartz filter and/or Gillian Air Sample Pump Kit with filter cassette. Monitoring Frequency: Continuous, to obtain results for lead and arsenic analysis. Based on analyses will determine if additional monitoring is necessary. <hr/> Dust control (i.e. spraying water) will be implemented as deemed necessary by the site supervisor and the SHSO. MIE MiniRam, or equivalent, may be used for dust monitoring. Note: _____						
Breathing Zone Reading (ppm)	Action																							
_____ to _____	Level D PPE																							
_____ to _____	Level C PPE																							
Greater than _____	Stop work. Evacuate the area. If upon return, levels still exceed _____, Level B PPE must be acquired and worn by trained personnel.																							
Breathing Zone Reading (ppm)	Action																							
_____ to _____	Level D PPE																							
_____ to _____	Level C PPE																							
Greater than _____	Stop work. Evacuate the area. If upon return, levels still exceed _____, Level B PPE must be acquired and worn by trained personnel.																							

ATTACHMENT E

Attachment E

Personal Protective Equipment Per Task

Applies to Task: ☒ ① ☐ ② ☐ ③ ☒ ④ ☐ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

<input checked="" type="checkbox"/> <i>Modified Level D*</i>		<input type="checkbox"/> <i>Level C*</i>		<input type="checkbox"/> <i>Level B*</i>	
<i>Equipment</i>	<i>Material/Type</i>	<i>Equipment</i>	<i>Material/Type</i>	<i>Equipment</i>	<i>Material/Type</i>
<input checked="" type="checkbox"/> Protective clothing	Tyvek	<input type="checkbox"/> Full-face air-purifying respirator	Cartridge Type:	<input type="checkbox"/> SCBA (pressure demand)	
<input checked="" type="checkbox"/> Outer gloves	latex or nitrile	<input type="checkbox"/> Half-mask air-purifying respirator	Cartridge Type:	<input type="checkbox"/> Air-line System (pressure demand)	
<input type="checkbox"/> Outer boots		<input type="checkbox"/> Protective clothing		<input type="checkbox"/> Protective clothing	
<input type="checkbox"/> Hard hat**		<input type="checkbox"/> Outer gloves		<input type="checkbox"/> Outer gloves	
<input type="checkbox"/> Safety glasses**		<input type="checkbox"/> Inner gloves		<input type="checkbox"/> Inner gloves	
<input checked="" type="checkbox"/> Hard-toed boots**	leather	<input type="checkbox"/> Outer boots		<input type="checkbox"/> Outer boots	
<input type="checkbox"/> Hearing protection**		<input type="checkbox"/> Hard hat**		<input type="checkbox"/> Hard hat**	
<input type="checkbox"/> Other:		<input type="checkbox"/> Safety glasses**		<input type="checkbox"/> Hard-toed boots**	
		<input type="checkbox"/> Hard-toed boots**		<input type="checkbox"/> Hearing protection**	
		<input type="checkbox"/> Hearing protection**		<input type="checkbox"/> Escape respirator**	
		<input type="checkbox"/> Other:		<input type="checkbox"/> Safety "tag" rope**	
				<input type="checkbox"/> Other:	

* If checked, indicates initial level of PPE. Other completed columns indicate information to upgrade/downgrade.

** Optional as applicable

Attachment E

Personal Protective Equipment Per Task

Applies to Task: ☒ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

<input type="checkbox"/> <i>Modified Level D*</i>		<input checked="" type="checkbox"/> <i>Level C*</i>		<input type="checkbox"/> <i>Level B*</i>	
<i>Equipment</i>	<i>Material/Type</i>	<i>Equipment</i>	<i>Material/Type</i>	<i>Equipment</i>	<i>Material/Type</i>
<input type="checkbox"/> Protective clothing		<input checked="" type="checkbox"/> Full-face air-purifying respirator	Cartridge Type: high-efficiency particulate filter	<input type="checkbox"/> SCBA (pressure demand)	
<input type="checkbox"/> Outer gloves		<input type="checkbox"/> Half-mask air-purifying respirator	Cartridge Type:	<input type="checkbox"/> Air-line System (pressure demand)	
<input type="checkbox"/> Outer boots		<input checked="" type="checkbox"/> Protective clothing	Tyvek	<input type="checkbox"/> Protective clothing	
<input type="checkbox"/> Hard hat**		<input checked="" type="checkbox"/> Outer gloves	nitrile	<input type="checkbox"/> Outer gloves	
<input type="checkbox"/> Safety glasses**		<input checked="" type="checkbox"/> Inner gloves	latex or nitrile	<input type="checkbox"/> Inner gloves	
<input type="checkbox"/> Hard-toed boots**		<input checked="" type="checkbox"/> Outer boots	latex rubber	<input type="checkbox"/> Outer boots	
<input checked="" type="checkbox"/> Hearing protection**		<input checked="" type="checkbox"/> Hard hat**	safety hat	<input type="checkbox"/> Hard hat**	
<input type="checkbox"/> Other:		<input checked="" type="checkbox"/> Safety glasses**	Safety glasses	<input type="checkbox"/> Hard-toed boots**	
		<input checked="" type="checkbox"/> Hard-toed boots**	leather	<input type="checkbox"/> Hearing protection**	
		<input checked="" type="checkbox"/> Hearing protection**	ear plugs	<input type="checkbox"/> Escape respirator**	
		<input checked="" type="checkbox"/> Other: air monitoring	meter(s)	<input type="checkbox"/> Safety "tag" rope**	
		Based on air monitoring, decision will be made in the field to downgrade.		<input type="checkbox"/> Other:	

* If checked, indicates initial level of PPE. Other completed columns indicate information to upgrade/downgrade.

** Optional as applicable

ATTACHMENT F

Attachment F

Decontamination Procedures and Equipment Directory

<i>Included in HASP</i>	<i>Level of Protection</i>
<input checked="" type="checkbox"/>	Modified Level D
<input checked="" type="checkbox"/>	Level C
<input type="checkbox"/>	Level B

Decontamination Procedures and Equipment – Modified Level D –

Applies to Task: ☒ ① ☒ ② ☒ ③ ☒ ④ ☒ ⑤ ☒ ⑥ ☐ ⑦ ☐ ⑧

Decontamination Solution: alconox and water

<i>Procedure</i>		<i>Equipment Needed</i>
Station 1	Deposit equipment on plastic drop cloth, or in plastic containers lined with plastic trash bags	Various size containers, plastic trash bags, plastic drop cloth
Station 2	Scrub outer boot covers and gloves with decontamination solution	Containers (20 to 30 gal), decontamination solution, long-handled scrub brushes
Station 3	Rinse off decontamination solution from Station 2 using copious amounts of water	Containers (20 to 30 gal), water, long-handled scrub brushes
Station 4	Remove tape around boots and gloves and deposit in containers lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags
Station 5	Remove boot covers and outer gloves and deposit in containers lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags, bench or stool
Station 6	Remove splash suit. Deposit in container lined with plastic trash bag.	Containers (20 to 30 gal), plastic trash bags, bench or stool
Station 7	Remove inner gloves and deposit in container lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags

Decontamination Procedures and Equipment – Level C –

Applies to Task: ☒ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

Decontamination Solution: alconox and water

<i>Procedure</i>		<i>Equipment Needed</i>
Station 1	Deposit equipment on plastic drop cloth, or in plastic containers lined with plastic trash bags	Various size containers, plastic trash bags, plastic drop cloth
Station 2	Scrub outer boot covers and gloves with decontamination solution	Containers (20 to 30 gal), decontamination solution, long-handled scrub brushes
Station 3	Rinse off decontamination solution from Station 2 using copious amounts of water	Containers (20 to 30 gal), water, long-handled scrub brushes
Station 4	Remove tape around boots and gloves and deposit in containers lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags
Station 5	Remove boot covers and outer gloves and deposit in containers lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags, bench or stool
Station 6	Wash chemical-resistant splash suit, gloves, and safety boots. Scrub with long-handled scrub brush and decontamination solution.	Containers (20 to 30 gal), decontamination solution, long-handled scrub brushes
Station 7	Rinse off decontamination solution using copious amounts of water	Containers (20 to 30 gal), water, long-handled scrub brushes
Station 8	Worker's respirator cartridges are exchanged, new outer gloves and boot covers donned, and joints taped. Worker returns to duty	Respirator cartridges, tape, boot covers, gloves
Station 9	Remove safety boots and deposit in container lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags, bench or stool, boot jack
Station 10	Remove splash suit. Deposit in container lined with plastic trash bag	Table
Station 11	Wash inner gloves with decontamination solution	Basin or bucket, decontamination solution, small table

Decontamination Procedures and Equipment

– Level C –

(continued)

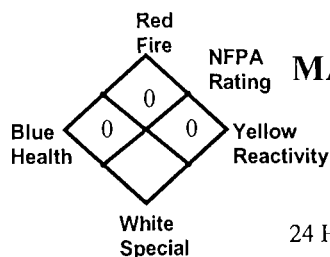
Applies to Task: ☒ ① ☒ ② ☒ ③ ☐ ④ ☒ ⑤ ☐ ⑥ ☐ ⑦ ☐ ⑧

Decontamination Solution: alconox and water

<i>Procedure</i>		<i>Equipment Needed</i>
Station 12	Rinse inner gloves with water	Water, basin or bucket, small table
Station 13	Remove air purifying respirator. Deposit in container lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags
Station 14	Remove inner gloves and deposit in container lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags
Station 15	Remove inner clothing. Place in container lined with plastic trash bag	Containers (20 to 30 gal), plastic trash bags
Station 16	Shower if highly toxic, skin-corrosive, or skin absorbable materials are known or suspected to be present	Water, soap, small table, basin or bucket, field showers, towels
Station 17	Put on clean clothes	Dressing shelter, tables, chairs, lockers, clothes

ATTACHMENT G

Alconox®



MATERIAL SAFETY DATA SHEET

Alconox, Inc.
30 Glenn Street, Suite 309
White Plains, NY 10603

24 Hour Emergency Number – Chem-Tel (800) 255-3924

I. IDENTIFICATION

Product Name (as appears on label)	ALCONOX
CAS Registry Number:	Not Applicable
Effective Date:	January 1, 1999
Chemical Family:	Anionic Powdered Detergent
Manufacturer Catalog Numbers for sizes	1104, 1125, 1150, 1101, 1103 and 1112

II. HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

There are no hazardous ingredients in ALCONOX as defined by the OSHA Standard and Hazardous Substance List 29 CFR 1910 Subpart Z.

III. PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point (F):	Not Applicable
Vapor Pressure (mm Hg):	Not Applicable
Vapor Density (AIR=1):	Not Applicable
Specific Gravity (Water=1):	Not Applicable
Melting Point:	Not Applicable
Evaporation Rate (Butyl Acetate=1):	Not Applicable
Solubility in Water:	Appreciable-Soluble to 10% at ambient conditions
Appearance:	White powder interspersed with cream colored flakes.

IV. FIRE AND EXPLOSION DATA

Flash Point (Method Used):	None
Flammable Limits:	LEL: No Data UEL: No Data
Extinguishing Media:	Water, dry chemical, CO ₂ , foam
Special Fire fighting Procedures:	Self-contained positive pressure breathing apparatus and protective clothing should be worn when fighting fires involving chemicals.
Unusual Fire and Explosion Hazards:	None

V. REACTIVITY DATA

Stability:	Stable
Hazardous Polymerization:	Will not occur
Incompatibility (Materials to Avoid):	None
Hazardous Decomposition or Byproducts:	May release CO ₂ on burning

VI. HEALTH HAZARD DATA

Route(s) of Entry:	Inhalation? Yes Skin? No Ingestion? Yes
Health Hazards (Acute and Chronic):	Inhalation of powder may prove locally irritating to mucous membranes. Ingestion may cause discomfort and/or diarrhea. Eye contact may prove irritating.
Carcinogenicity:	NTP? No IARC Monographs? No OSHA Regulated? No
Signs and Symptoms of Exposure:	Exposure may irritate mucous membranes. May cause sneezing.
Medical Conditions Generally Aggravated by Exposure:	Not established. Unnecessary exposure to this product or any industrial chemical should be avoided. Respiratory conditions may be aggravated by powder.
Emergency and First Aid Procedures:	Eyes: Immediately flush eyes with water for at least 15 minutes. Call a physician. Skin: Flush with plenty of water. Ingestion: Drink large quantities of water or milk. Do not induce vomiting. If vomiting occurs administer fluids. See a physician for discomfort.

VII. PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken if Material is Released or Spilled:	Material foams profusely. Recover as much as possible and flush remainder to sewer. Material is biodegradable.
Waste Disposal Method:	Small quantities may be disposed of in sewer. Large quantities should be disposed of in accordance with local ordinances for detergent products.
Precautions to be Taken in Storing and Handling:	Material should be stored in a dry area to prevent caking.
Other Precautions:	No special requirements other than the good industrial hygiene and safety practices employed with any industrial chemical.

VIII. CONTROL MEASURES

Respiratory Protection (Specify Type):	Dust mask - Recommended
Ventilation:	Local Exhaust-Normal Special-Not Required Mechanical-Not Required Other-Not Required
Protective Gloves:	Impervious gloves are useful but not required.
Eye Protection:	Goggles are recommended when handling solutions.
Other Protective Clothing or Equipment:	None
Work/Hygienic Practices:	No special practices required

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH BUT NO WARRANTY IS EXPRESSED OR IMPLIED.

International Chemical Safety Cards

BENTONITE

ICSC: 0384

BENTONITE Wilkinite			
CAS # 1302-78-9 RTECS # CT9450000 ICSC # 0384			
TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/ SYMPTOMS	PREVENTION	FIRST AID/ FIRE FIGHTING
FIRE	Not combustible.		In case of fire in the surroundings: all extinguishing agents allowed.
EXPLOSION			
EXPOSURE		PREVENT DISPERSION OF DUST!	
• INHALATION		Avoid inhalation of fine dust and mist.	
• SKIN		Protective gloves.	
• EYES		Safety spectacles.	
• INGESTION			
SPILLAGE DISPOSAL	STORAGE		PACKAGING & LABELLING
Sweep spilled substance into containers; if appropriate, moisten first to prevent dusting (extra personal protection: P1 filter respirator for inert particles).			
SEE IMPORTANT INFORMATION ON BACK			
ICSC: 0384		Prepared in the context of cooperation between the International Programme on Chemical Safety & the Commission of the European Communities © IPCS CEC 1993	

International Chemical Safety Cards

BENTONITE

ICSC: 0384

<p>I M P O R T A N T D A T A</p>	<p>PHYSICAL STATE; APPEARANCE: ODOURLESS GRANULES OR POWDER IN VARIABLE COLOUR.</p> <p>PHYSICAL DANGERS:</p> <p>CHEMICAL DANGERS: The substance is a weak base in suspension in water.</p> <p>OCCUPATIONAL EXPOSURE LIMITS (OELs): TLV not established.</p>	<p>ROUTES OF EXPOSURE: The substance can be absorbed into the body by inhalation of dust.</p> <p>INHALATION RISK: Evaporation at 20°C is negligible; a harmful concentration of airborne particles can, however, be reached quickly.</p> <p>EFFECTS OF SHORT-TERM EXPOSURE:</p> <p>EFFECTS OF LONG-TERM OR REPEATED EXPOSURE: The substance may have effects on the lungs , resulting in silicosis due to the presence of crystalline silica (see ICSC # 0808).</p>
<p>PHYSICAL PROPERTIES</p>	<p>Relative density (water = 1): 2.5 Solubility in water: none</p>	
<p>ENVIRONMENTAL DATA</p>		
<p>NOTES</p>		
<p>Bentonites are aluminate silicate and can contain crystalline silica. The content varies widely from less than 1% to about 24%.</p>		
<p>ADDITIONAL INFORMATION</p>		
<p>ICSC: 0384 BENTONITE</p> <p style="text-align: center;">© IPCS, CEC, 1993</p>		
<p>IMPORTANT LEGAL NOTICE:</p>	<p>Neither the CEC or the IPCS nor any person acting on behalf of the CEC or the IPCS is responsible for the use which might be made of this information. This card contains the collective views of the IPCS Peer Review Committee and may not reflect in all cases all the detailed requirements included in national legislation on the subject. The user should verify compliance of the cards with the relevant legislation in the country of use.</p>	

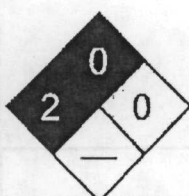
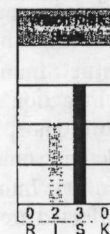
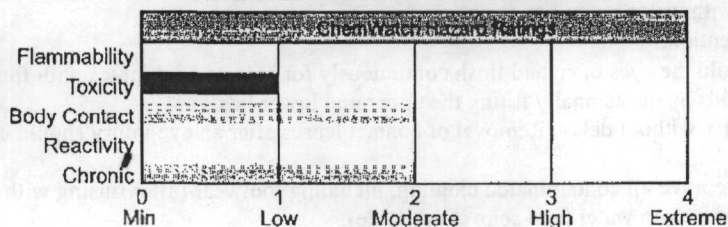
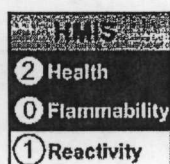
Section 1 - Chemical Product and Company Identification 54.1

Material Name: Portland Cement **CAS Number:** 65997-15-1
Chemical Formula: Unspecified or Variable
Synonyms: CEMENT; HYDRAULIC CEMENT; PORTLAND CEMENT; PORTLAND CEMENT SILICATE
General Use: Hydraulic binder used for mixing concrete, concrete masonry, mortars and grouts; also soil stabilization.

Section 2 - Composition / Information on Ingredients

Name	CAS	%
portland cement	65997-15-1	varies
OSHA PEL TWA: 15 mg/m ³ ; total dust.	NIOSH REL No data found.	DFG (Germany) MAK TWA: 5 mg/m ³ .
OSHA PEL Vacated 1989 Limits TWA: 10 mg/m ³ ; total. Other Values: respirable mg/m ³ ; 5.	IDLH Level 5000 mg/m ³ .	
ACGIH TLV TWA: 10 mg/m ³ .		

Section 3 - Hazards Identification



Fire Diamond

ANSI Signal Word

Caution

☆☆☆☆☆ Emergency Overview ☆☆☆☆☆

Gray powder; odorless. Irritating to eyes/skin/respiratory tract. Also causes (on contact with wet cement): corneal edema, dermatitis, cracked skin. Chronic: bronchitis, dermatitis.

Potential Health Effects

Primary Entry Routes: inhalation, ingestion, skin contact

Target Organs: respiratory system, skin, eyes

Acute Effects

Inhalation: Generated dust may be highly discomforting if inhaled and may even cause in some cases, sensitization. Respiratory sensitization may result in allergic/asthma like responses; from coughing and minor breathing difficulties to bronchitis with wheezing, gasping. Effects on lungs are significantly enhanced in the presence of respirable particles.

Eye: The solid/dust is highly discomforting, may be abrasive to the eyes and capable of causing a mild, temporary redness of the conjunctiva (similar to wind-burn), temporary impairment of vision and/or other transient eye damage/ulceration.

Skin: The dust is extremely discomforting to the skin and is capable of causing skin reactions which may lead to dermatitis.

Handling wet cement can cause dermatitis. Cement when wet is quite alkaline and this alkali action on the skin contributes strongly to cement contact dermatitis since it may cause drying and defatting of the skin which is followed by hardening, cracking, lesions developing, possible infections of lesions and penetration by soluble salts. Cement contact dermatitis (CCD) may occur when contact shows an allergic response, which may progress to sensitization. Sensitization is due to soluble chromates (chromate compounds) present in trace amounts in some cements, cement products. Soluble chromates readily penetrate intact skin.

Cement dermatitis can be characterized by fissures, eczematous rash, dystrophic nails, and dry skin; acute contact with highly alkaline mixtures may cause localized necrosis.

Ingestion: Considered an unlikely route of entry in commercial/industrial environments.

The material is harmful if swallowed.

The dust is discomforting to the gastrointestinal tract.

Carcinogenicity: NTP - Not listed; IARC - Not listed; OSHA - Not listed; NIOSH - Not listed; ACGIH - Not listed; EPA - Not listed; MAK - Not listed.

Chronic Effects: Cement eczema may be due to chromium in feed stocks or contamination from materials of construction. Sensitization to chromium may be the leading cause of nickel and cobalt sensitivity and the high alkalinity of cement is an important factor in cement dermatoses.

Repeated, prolonged severe inhalation exposure may cause pulmonary edema and rarely, pulmonary fibrosis. Workers may also suffer from dust-induced bronchitis with chronic bronchitis reported in 17% of a group occupationally exposed to high dust levels.

Data suggests that occupational exposure to Portland cement dust may lead to a higher incidence of chronic respiratory symptoms and a reduction of ventilatory capacity.

Section 4 - First Aid Measures

Inhalation: Remove to fresh air.

Encourage patient to blow nose to ensure clear breathing passages.

Ask patient to rinse mouth with water but to not drink water.

Seek immediate medical attention.

Eye Contact: Immediately hold the eyes open and flush continuously for at least 15 minutes with fresh running water.

Ensure irrigation under eyelids by occasionally lifting the upper and lower lids.

Transport to hospital or doctor without delay. Removal of contact lenses after an eye injury should only be undertaken by skilled personnel.

Skin Contact: Immediately remove all contaminated clothing, including footwear (after rinsing with water).

Wash affected areas thoroughly with water (and soap if available).

Seek medical attention in event of irritation.

Ingestion: Contact a Poison Control Center.

Do NOT induce vomiting. Give a glass of water.

After first aid, get appropriate in-plant, paramedic, or community medical support.

Note to Physicians: Treat symptomatically as for strong alkaline material.

Section 5 - Fire-Fighting Measures

Flash Point: Noncombustible

Autoignition Temperature: Not applicable

LEL: Not applicable

UEL: Not applicable

Extinguishing Media: If small amounts are involved in a fire, there is no restriction on the type of extinguisher. Otherwise, use LARGE AMOUNTS of water to absorb heat generated.

General Fire Hazards/Hazardous Combustion Products: Noncombustible.

Not considered to be a significant fire risk; however, containers may burn.

Decomposes on heating and produces toxic fumes of caustic compounds.

Fire Incompatibility: No known incompatibility with normal range of industrial materials.

Fire-Fighting Instructions: Contact fire department and tell them location and nature of hazard.

Wear breathing apparatus plus protective gloves for fire only. Prevent, by any means available, spillage from entering drains or waterways.

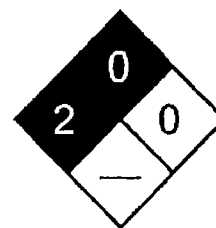
Use fire fighting procedures suitable for surrounding area.

Do not approach containers suspected to be hot.

Cool fire-exposed containers with water spray from a protected location.

If safe to do so, remove containers from path of fire.

Equipment should be thoroughly decontaminated after use.



Fire Diamond

Section 6 - Accidental Release Measures

Small Spills: Clean up all spills immediately. Avoid contact with skin and eyes.

Wear protective clothing, gloves, safety glasses and dust respirator.

Use dry clean-up procedures and avoid generating dust.
 Vacuum up or sweep up. Place in clean drum then flush area with water.
Large Spills: Clear area of personnel and move upwind.
 Use dry clean-up procedures. Avoid generating dust.
 If inhalation risk of exposure exists, wear NIOSH-approved dust respirator.
 Collect recoverable product into labeled containers for recycling.
Regulatory Requirements: Follow applicable OSHA regulations (29 CFR 1910.120).

Section 7 - Handling and Storage

Handling Precautions: Avoid generating and breathing dust. Limit all unnecessary personal contact.
 Wear protective clothing when risk of exposure occurs.
 Use in a well-ventilated area. Atmosphere should be checked against exposure standards to ensure safe working conditions are maintained.
 Avoid contact with incompatible materials.
 When handling, DO NOT eat, drink or smoke.
 Always wash hands with soap and water after handling.
 Use good occupational work practices.
 Observe manufacturer's storing and handling recommendations.
Recommended Storage Methods: Packaging as recommended by manufacturer.
 Check that containers are clearly labeled.
 Metal pail or Paper bag with sealed plastic liner.
 Multi-ply woven plastic or paper bag with sealed plastic liner.
Regulatory Requirements: Follow applicable OSHA regulations.

Section 8 - Exposure Controls / Personal Protection

Engineering Controls: Use in a well-ventilated area.
 If exposure to workplace dust is not controlled, respiratory protection is required; wear NIOSH-approved dust respirator.
 General exhaust is adequate under normal operating conditions.
 If risk of overexposure exists, wear NIOSH-approved dust respirator.
 Correct fit is essential to obtain adequate protection.
Personal Protective Clothing/Equipment
Eyes: Safety glasses with side shields; or as required, chemical goggles.
 Contact lenses pose a special hazard; soft lenses may absorb irritants and all lenses concentrate them.
Hands/Feet: Barrier cream and Wear chemical protective gloves, eg. PVC.
 Wear safety footwear or safety gumboots, eg. Rubber.
Respiratory Protection:
 Exposure Range >5 to 50 mg/m³: Air Purifying, Negative Pressure, Half Mask
 Exposure Range >50 to 500 mg/m³: Air Purifying, Negative Pressure, Full Face
 Exposure Range >500 to <5000 mg/m³: Supplied Air, Constant Flow/Pressure Demand, Full Face
 Exposure Range 5000 to unlimited mg/m³: Self-contained Breathing Apparatus, Pressure Demand, Full Face
 Cartridge Color: dust/mist filter (use P100 or consult supervisor for appropriate dust/mist filter)
Other: Overalls. Eyewash unit. Ensure there is ready access to a safety shower.

Section 9 - Physical and Chemical Properties

Appearance/General Info: Finely divided grey to off-white colored powder with no odor. Hardens after reaction with water. A finely ground mixture of cement clinker and gypsum, surface area 300-500 m²/kg (Blaine Method).

Physical State: Divided solid	Evaporation Rate: Not applicable
Vapor Pressure (kPa): Not applicable	pH: alkaline
Vapor Density (Air=1): Not applicable	Boiling Point Range: No data found.
Formula Weight: Not applicable.	Freezing/Melting Point Range: > 1200 °C (2192 °F)
Specific Gravity (H₂O=1, at 4 °C): 3.0-3.2	Decomposition Temperature (°C): Not applicable
Water Solubility: Insoluble	

Section 10 - Stability and Reactivity

Stability/Polymerization: Product is considered stable. Hazardous polymerization will not occur.
Storage Incompatibilities: Segregate from strong oxidizers and strong acids.

Section 11 - Toxicological Information

No relevant toxicological data found at time of research.

See NIOSH, RTECS VV 8770000, for additional data.

Section 12 - Ecological Information

Environmental Fate: No data found.

Ecotoxicity: No data found.

Section 13 - Disposal Considerations

Disposal: Recycle wherever possible or consult manufacturer for recycling options.

Follow applicable federal, state, and local regulations.

Bury residue in an authorized landfill.

Recycle containers where possible, or dispose of in an authorized landfill.

Section 14 - Transport Information**DOT Transportation Data (49 CFR 172.101):**

Shipping Name: NONE

Additional Shipping Information:

Hazard Class: None

ID No.: None

Packing Group: None

Label: No class label assigned

Section 15 - Regulatory Information**EPA Regulations:**

RCRA 40 CFR: Not listed

CERCLA 40 CFR 302.4: Not listed

SARA 40 CFR 372.65: Not listed

SARA EHS 40 CFR 355: Not listed

TSCA: Listed

Section 16 - Other Information

Research Date:1999-11 **Review Date:**2000-07

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CAS # 65997-15-1

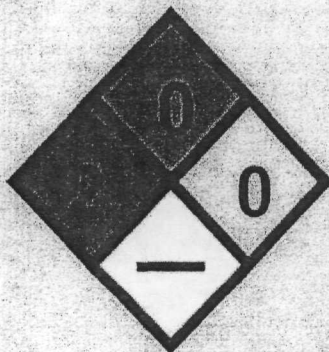
Caution

13

Portland Cement

hydraulic cement; portland cement silicate

Gray powder; odorless. Irritating to eyes/skin/respiratory tract. Also Causes (on contact with wet cement): corneal edema, skin burns, dermal necrosis, first/second/third degree burns, esophagus/stomach burns. Chronic: bronchitis, dermatitis.



Target Organs



Eyes



Skin



Respiratory
System

3910

Personal Protective Equipment

8



Goggles



Gloves



Apron

Check
to
see

is respirator
required?

Emergency Procedures



First Aid

4

Inhalation: Remove to fresh air and support breathing. Eyes/Skin: Flush with flooding amounts of water. Thoroughly wash skin with soap and water. Ingestion: Do not induce vomiting. Contact physician immediately.



Fire

5

Noncombustible. Use agent suitable for surrounding fire.



Spills & Leaks

6


Notify safety personnel, isolate and ventilate area, deny entry, and stay upwind. DO NOT SWEEP! Carefully scoop up or vacuum (with a HEPA filter). Cleanup crew should protect against exposure.

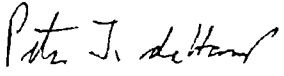
Consult MSDS 0718 for more information


APPENDIX D SOPs

STANDARD OPERATING PROCEDURE NO. 100

WATER LEVEL MEASUREMENT PROCEDURES

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 100

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	2

STANDARD OPERATING PROCEDURE NO. 100 WATER LEVEL MEASUREMENT PROCEDURES

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for conducting water level measurements in monitoring wells during field investigations at hazardous and non-hazardous waste sites. A water level measurement form is provided with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of water level measurements is to gain accurate measurements (to within 0.01 ft) of the depth of groundwater for use during well installation, potentiometric mapping, purge volume calculations during groundwater sampling, slug tests, packer tests, and pump tests.

1.3 Equipment

The following items of equipment will be used during water level measurements.

- graduated electronic water level indicator;
- tap water;
- Alconox®, Liquinox®, or other non-phosphate concentrated laboratory-grade detergent;
- deionized water;
- pump sprayer or pint squeeze bottles;
- Personal Protective Equipment (PPE), as required by HASP; for contaminated sites, one pair of gloves per well/piezometer;
- air monitoring equipment as required by HASP;
- field log book and water level measurement form as dictated by FSP;
- well keys; and
- oil/water interface probe, if non-aqueous phase liquid (NAPL) suspected.

2. PROCEDURES

The following procedures will be followed during water level measurements.


1. Fill one squeeze bottle or sprayer with detergent/water solution and a second with deionized water.
2. Record the condition of the well (protective casing, concrete collar, lock in place etc.) in the field log book or water level measurement form.
3. Check that the water level tape has no obvious kinks or damage.
4. Don PPE per the HASP, including a new set of gloves for each well. Stand upwind of the well; unlock and open the well. If a vented cap is present, conduct well mouth air monitoring from the vent per the HASP. If a non-vented well cap is present, remove the cap and monitor the well mouth

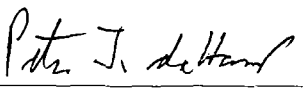
immediately. Record all pertinent air monitoring results (sustained, dissipating, background, odor).

5. Identify the previous measuring point marking or notch on the riser or casing (if present). Record this location in the field log book or on the water level measurement form.
6. Using a previously decontaminated water level indicator, turn on the meter, check the audible indicator, reel the electronic probe into the well riser (with the increments visible) slowly until the meter sounds, grasp the tape with hand, withdraw the tape and lower it again slowly until the sound is again audible. Check the depth to water on the tape and make a mental note of the depth to within 0.01-ft. Lower the probe again slowly and repeat the measurement for accuracy. A one-ft error is the most common measurement type during water level measurements. Be sure to read the depth correctly on the tape.
7. Record the depth to water from the measuring point and the measurement time in the field log book or on the water level measurement form.
8. If it is necessary to identify NAPL, this SOP will be modified to include the use of the oil/water interface probe. The procedures during the use of this probe should be implemented similarly and per the manufacturers' specifications. Through the use of this probe, product thickness can be determined.
9. Decontaminate the probe, the portion of tape that was submerged, and any obviously soiled tape. Wipe the probe with a paper towel soaked in detergent solution, followed by rinsing by spraying the probe with deionized water. Next, wipe the affected portion of the tape with a paper towel soaked in detergent solution followed by a paper towel soaked in deionized water.

STANDARD OPERATING PROCEDURE NO. 110

GROUNDWATER SAMPLING USING THE LOW-FLOW PROTOCOL

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 110

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment and Supplies	1
2. PROCEDURES.....	3
2.1 Pre-Mobilization Activities.....	3
2.2 Pre-Sampling Procedures.....	3
2.2.1 Inventory	3
2.2.2 Calibration.....	4
2.2.3 Well Inspection	4
2.3 Well Purging and Sampling	4
2.3.1 Set-up	4
2.3.2 Purging (Low Flow Protocol)	5
2.3.3 Variations from Low Flow Protocol	6
2.3.4 Field Measurements	7
2.3.5 Sampling	7
2.3.6 Observations During Sampling.....	8
2.3.7 Storage and Shipping	9
2.4 Documentation.....	9

ATTACHMENT A- Background on low flow/minimal drawdown purging

STANDARD OPERATING PROCEDURE 110 GROUNDWATER SAMPLING USING THE LOW-FLOW PROTOCOL

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to provide instructions for groundwater sampling using the USEPA low-flow/minimal drawdown well purging protocol. Included in this SOP are field forms for sampling and meter calibration, instructions, and directions for documentation.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of low flow sampling techniques is to collect a representative groundwater sample from a monitoring well.

1.3 Equipment and Supplies

Pump and probe selection may differ depending on the well diameter, groundwater constituents, and depth to groundwater, but generally, sampling will require the following equipment:

- Peristaltic, bladder, submersible, or Waterra pump capable of a flow rate between 50 and 500 mL/minute and appropriate power supply, including compressor if needed. The pump type will principally depend on the depth to water and well diameter. Bladder or submersible pumps are preferred, peristaltic pumps are acceptable only for wells where the depth to water is less than about 25 feet, and Waterra pumps are only recommended for narrow diameter wells that cannot be sampled using a bladder or peristaltic pump.
- Field probe and flow-through cell (e.g., YSI) for measuring pH, temperature, conductance (and/or specific conductance), dissolved oxygen (DO), and oxidation-reduction potential (ORP) of groundwater, and a turbidity meter.
- Calibration solutions for the field probes, per manufacturer's requirements.
- Water level tape.
- Polyethylene tubing, connections, and tools as appropriate; sufficient tubing to dedicate to each well.
- In-line filter apparatus (0.45-micron).
- Graduated cylinder or 1-liter bottle and stopwatch.
- 5-gallon bucket and funnel for purge water.
- Field forms for meter calibration and groundwater sample collection (included in SOP) and log book as specified in FSP.
- Personal Protective Equipment (PPE) (as specified in the HASP).
- Air monitoring equipment as specified in HASP.
- Decontamination supplies as specified in FSP and QAPP.
- Sample containers and cooler.
- Clean plastic sheeting, paper towels, and miscellaneous supplies.
- pH paper.
- Field test kits for ferrous iron, sulfide, and alkalinity.

2. PROCEDURES

2.1 Pre-Mobilization Activities

- Obtain the construction, diameter, depth, material, screened interval, and map showing location for each monitoring well to be sampled.
- Obtain a listing of the parameters that will be measured in the field or laboratory as part of this sampling program including the required analytical method, sample volume, and holding time for each parameter. The parameters that will be measured in the field are the low-flow stabilization parameters including temperature, pH, specific conductance, ORP, DO, and turbidity. These parameters will be recorded during low flow purging and immediately prior to collection of samples for laboratory analysis. In addition, certain geochemical parameters, such as ferrous iron, will be measured in the field through test kits. Remaining parameters will be measured in the laboratory.
- Verify that all equipment on order is being shipped to the site.

2.2 Pre-Sampling Procedures

Several steps are required before sampling any of the wells. These steps ensure that instruments are functioning and properly calibrated and that the necessary equipment has been supplied for efficient and accurate sampling.

Inventory

Verify that the correct equipment has been received by the field site and that it is clean (decontaminated). Inventory sample containers to verify that the laboratory has provided the correct number of containers of the proper size and containing the correct preservative if required. To the extent possible, pre-label/tag and bundle sample containers for each well to avoid confusion during sample collection.

Verify that the appropriate PPE and ancillary supplies (e.g., paper towels, decontamination solution) have been received by the field site. The appropriate protective equipment, as specified in the HASP, will be reviewed during a morning tailgate meeting. Contact the field manager or project manager immediately if there are discrepancies.

2.2.2 Calibration

Calibrate the field probes consistent with the manufacturer's specifications before sampling and at the start of each field day. Record the calibration data on the field calibration form provided in this SOP. A check of the calibration shall be performed at least once more during the field day. Instruments will be recalibrated as necessary (e.g., when calibration checks indicate incorrect operation) to ensure accurate measurements, and all checks and recalibrations will be recorded on field calibration forms. Calibration will also be checked if any readings during sampling are suspect.

2.2.3 Well Inspection

Inspect the well for the presence of lock and cap, surface seal integrity, obstructions, evidence of tampering, debris, or surface water collecting in flush mounts. Note any irregularities in the groundwater sampling field form included with this SOP.

2.3 Well Purging and Sampling

Sampling is performed in teams according to the health and safety protocol for the site. Sampling is performed using a five-step procedure that will be followed upon arrival at each well:

1. set-up;
2. purging;
3. measurement of field parameters and field testing;
4. sampling; and
5. clean-up and decontamination.

Detailed procedures for performing each of these steps are provided in the following subsections.

2.3.1 Set-up

All necessary equipment for purging, sampling, and storage will be brought to the well before the well is opened. Equipment will be placed on a clean plastic sheet near the well. General parameters describing the well and field condition (e.g., well identification, depth, weather, date, and time) will be documented on a field data sheet. PPE, as required by the HASP, will be donned prior to opening well, and air monitoring

will be performed per HASP requirements while opening well. Sampling begins by opening the well and measuring the depth to the water table. The tubing, field probe, and reservoir for purged water are then set up.

2.3.2 Purging (Low Flow Protocol)

Wells are purged using the low flow/minimum drawdown protocol as described by Puls and Barcelona (1996) and summarized below. The general procedural requirements for low-flow purging are listed below.

- Lower the pump slowly down the well, positioning the well intake at the middle of the well screen.
- Minimize disturbance of the water column in the well by initiating pumping at a low rate (see below). Dedicated tubing (left in-place between sampling events) is also recommended to minimize disturbance to the water column before and during sampling.
- Begin pumping at a steady rate of 100 mL/min and measure the depth to water frequently (e.g., every minute for the first few minutes) to ensure that less than 0.1 ft of drawdown occurs. The pumping rate may be increased if drawdown is less than 0.1 ft, but the pumping rate will not exceed 500 mL/min. In some silty and/or clayey formations, drawdown may exceed 0.1 ft when pumping at 100 mL/min. If this occurs, refer to the sections on *Variations from Low Flow Protocol* for alternatives to the low flow/minimum drawdown protocol.
- Field parameters and depth to water will be recorded on field data sheets a minimum of every five minutes while purging. Purging will continue until pH, temperature, specific conductance, ORP, DO, and turbidity stabilize (three consecutive readings), which is defined as follows:
 - ± 0.1 units for pH;
 - $\pm 3\%$ for specific conductance;
 - ± 10 mV for ORP;
 - $\pm 10\%$ for temperature;
 - $\pm 10\%$ for turbidity; and
 - $\pm 10\%$ for DO.

- DO and turbidity tend to stabilize last and are better measures of sufficient purging. Drawdown should be minimized during purging and/or sampling, not exceeding 0.1 ft, if possible.
- In the case that the above criteria for stabilization are not met before three well volumes have been pumped, then a maximum of five well volumes will be pumped before samples are taken. Also, if stabilization has not occurred after two hours of purging regardless of well volume status, samples will be collected at this point.

2.3.3 Variations from Low Flow Protocol

Wells in low-yield formations such as poorly fractured bedrock and silt or clay soils may not yield sufficient water for purging (e.g., 100 mL/min) without more than 0.1 ft of drawdown. In these cases, a modified low-flow method will be used. Currently, there is no published protocol for sampling low-recharge wells. Two modifications described below have been endorsed at one site by USUSEPA for sampling and purging wells that yield less than 100 mL/min at a drawdown of 0.1 ft.

Alternative Method 1: Less than half the casing volume is located above the well screen

Purge the well with the pump intake located at the midpoint of the well screen by constant pumping at a rate no greater than 500 mL/min until the water level reaches the top of the well screen. Measure and record the field parameters and water depth at a minimum of five-minute intervals or at the end of every purge cycle, although it may be difficult to obtain stable measurements of certain parameters (i.e., DO, ORP, turbidity). Cease pumping and allow the water level to recover until the standing water column in the well (length from water level to bottom of well) equilibrates to at least 90% of the static water column. Repeat the purging and cessation cycle until a minimum of one casing volume is removed from the well. The well will then be allowed to recover sufficient volume to collect the required groundwater sample from the midpoint of the screened interval, within 24 hours of the last purging event.

Alternative Method 2: More than half the casing volume is located above the well screen

The well will be purged with the pump intake located at midpoint of the well screen at a rate no greater than 500 mL/min until the water level reaches the top of the well screen. This will remove at least one-half of a casing volume of water from the well. The well is then allowed eight hours to recover, after which time a volume of water equal to the casing volume of the screened interval will be removed, removing approximately a full

casing volume during the two purging events. Directly following the second purging event, the required groundwater sample is to be collected from the midpoint of the screened interval.

Other Modifications to Low Flow Sampling

Other modifications of the low-flow protocol may be required. Low-recharge wells screened across the water table are not amenable to either of the methods described above. It may not be practical to sample extremely low recharge wells using any of the cited modifications, in which case, it will be necessary to evacuate all casing water and re-sample as soon as sufficient recharge has entered the well to provide a sample. Data from such wells will be qualified to indicate the potential for sample bias.

2.3.4 Field Measurements

Field parameter measurements will be recorded following parameter stabilization (purging) and before sampling. The pumping rate and sampler intake location in the well are not to be adjusted after purging. The field parameters measured are pH, temperature, specific conductance, DO, ORP, and turbidity.

2.3.5 Sampling

Samples will be collected after field parameters have stabilized and measurements recorded. The pump rate and sample intake location will not be adjusted between purging and sampling. Samples are to be obtained from the influent line (prior) to the flow-through cell (i.e., field parameters cannot be measured during sampling). The following sampling strategy is to be followed at each location in its entirety prior to beginning a new location.

Sampling Methods by Analytical Group

Sample containers are to be filled in the order listed below and on the field data sheet using the following protocols. Note that many sample containers contain preservatives; hence, it is necessary to fill each container carefully enough to avoid or minimize overfilling, which may dilute the preservative to unacceptable levels. For each analysis, one of the corresponding containers will be tested with pH paper to confirm that the pH meets the corresponding limits stated in this SOP.

1. Volatile organic compound (VOC) samples will be collected first. Sample containers are to be completely filled so that a meniscus forms over the opening of the container. The container lid will be moistened with groundwater and screwed to the container body. The container is then turned upside down and

inspected for air bubbles. If air bubbles exist in the container, then it is “topped off” to eliminate bubbles. This procedure is repeated until there are no entrapped bubbles in the container. Filled samples are stored at 4°C ($\pm 2^\circ\text{C}$).

2. Geochemistry-related parameters are to be sampled in the following order and with the following procedure:
 - a) Alkalinity, ferrous iron, and sulfide measurements will be collected in the field per the field kit manufacturer’s instructions.
 - b) Major anions (sulfate, orthophosphate) – water will be dispensed into two 500 mL plastic bottles, sealed and stored at 4°C ($\pm 2^\circ\text{C}$).
 - c) Total Organic Carbon (TOC) – water will be dispensed into a 125 mL amber glass bottle with H_3PO_4 as a preservative to achieve a pH below 2, sealed, and stored at 4°C ($\pm 2^\circ\text{C}$).
3. After all of the geochemistry-related parameters are collected, the following samples are collected:
 - a) Semi-volatile organic compound (SVOC) – water will be dispensed into two 1,000 mL amber glass bottles without a preservative, sealed, and stored at 4°C ($\pm 2^\circ\text{C}$).
 - b) Metals – groundwater will be split into two portions; one filtered sample and one unfiltered sample. The filtered sample (for dissolved metals analysis) will be field-filtered using a clean, disposable, 0.45- μm filter attached in-line to the sample tubing. Filtered water will be dispensed into a 500 mL wide-mouth plastic bottle with HNO_3 as a preservative to achieve a pH below 2, sealed and stored at 4°C ($\pm 2^\circ\text{C}$). Unfiltered water (for total metals analysis) will be dispensed directly in to a 500 mL wide mouth plastic bottle with HNO_3 as a preservative to achieve a pH below 2, sealed, and stored at 4°C ($\pm 2^\circ\text{C}$).
 - c) Cyanide – water will be dispensed into one 1-L plastic bottle, preserved with NaOH to a pH of > 12 , sealed, and stored at 4°C ($\pm 2^\circ\text{C}$).

2.3.6 Observations During Sampling

Field sampling staff will identify and log any observations that may be considered unusual into a field notebook or on the groundwater sampling field form for each well. These observations include, but are not limited to: excessive bubbling within the tubing or in the sample containers as they are filled; odors such as sulfide; excessive turbidity, solids, or formation of precipitates in the samples; color changes in the water; and

unusual sounds made by the equipment. In addition, sampling personnel will note the condition of the well upon arrival and inspection. If the well casing is damaged and there are anomalies in the calculated water level at the well, then the casing damage may indicate compromised sample quality.

2.3.7 Storage and Shipping

All samples will be immediately placed on ice (preferably double-bagged wet ice packs) to remain at 4°C ($\pm 2^\circ\text{C}$) prior to and during shipment to the laboratory. The sample containers will be stored in a cooler until further processing. Refer to the SOP No. 410 for sample shipping.

2.4 Documentation

Field documentation includes completed calibration records, groundwater sampling field forms, and other field notes deemed relevant. It is essential that field data sheets be filled out completely and legibly at each location, and that entries are consistent for each location and among different personnel. As referenced above, groundwater sampling data and calibration forms are provided with this SOP. The following information will be recorded:

- job, site, date, and sampler;
- well identification and description;
- depth to water;
- casing volume calculation;
- depth of pump intake during purging and sampling;
- equipment used (field probes, tubing, model and serial numbers);
- purge rate, field parameters (temperature, conductivity, DO, ORP, pH, and turbidity) and depth to water recorded every 5 minutes;
- sampling parameters;
- stabilized field parameters;
- identification, time, container types, preservatives, and analytical methods for samples; and
- space for comments.

ATTACHMENT A

BACKGROUND ON LOW-FLOW/MINIMAL DRAWDOWN PURGING

Monitoring Well Sampling

The objective of groundwater sampling is to obtain a sample that is representative of groundwater quality under ambient flow conditions. To achieve this objective, a representative groundwater sample should contain: (i) the average concentration of all chemical constituents present in the target aquifer volume; (ii) constituents in the same phase and chemical speciation as present in-situ; and (iii) only the chemical constituents that are mobile under ambient groundwater flow conditions. The purpose of this section is to describe sampling practices that are most appropriate for investigations and to discuss key issues relevant to sampling. This discussion relies in part on sampling guidance developed by the USEPA.

Traditional methods of groundwater sampling call for purging three to five casing volumes of water from a well prior to sampling (Robbins and Martin-Hayden 1991, Barcelona *et al.* 1994, Wilson *et al.* 1995). These methods are no longer recommended by USEPA because they can induce bias through sample disturbance and particle mobilization, and produce larger volumes of purge water that increase exposure potential and disposal costs. Currently, USEPA recommends the low flow protocol for obtaining groundwater samples, although new sampling methods such as diffusion samplers are gaining regulatory acceptance in some situations. The low flow protocol and modifications to the low flow protocol that may be needed under some conditions are discussed in the following sections.

Note that although this document recommends low flow purging as the most widely accepted and reliable sampling method, modifications of the low flow protocol or other sampling protocols may be applicable in certain circumstances.

Low Flow Purging

The purpose of low flow purging is to draw sufficient water into the casing from the formation to produce a representative sample without generating excessive groundwater velocities outside the casing, which can bias the sample. Properly implemented in an appropriately constructed monitoring well, low flow purging induces lateral flow from the formation directly through the well screen and into the sampler intake. Several measurements that are often important for investigation and are particularly sensitive to sampling bias caused by high flow purging include concentrations of dissolved gases (O₂, CO₂, methane, ethane) total metals, and ORP. An additional advantage of low flow purging is that mixing between water entering the casing and stagnant water

existing in the casing is minimized, thus achieving stabilization of the purging parameters described below with less extracted volume than conventional purging.

Low flow purging uses the same stabilization criteria as conventional purging (i.e., stable temperature, DO, conductivity, E_h , pH, and turbidity), but requires careful flow regulation (typically at a rate of 0.1 to 0.5 L/min) to limit drawdown to the extent practical (less than 0.1 ft is the goal). Since low flow purging requires steady removal of water with minimal disturbance, grab samplers (e.g., bailers) cannot be used with the low flow protocol and are not recommended for either purging or sampling. According to Puls and Barcelona (1996), a representative sample can be collected when three successive measurements (taken at 5 minute intervals) are within ± 0.1 units for pH, $\pm 3\%$ for conductivity, ± 10 mV for E_h , and $\pm 10\%$ for turbidity and DO. The low flow sampling protocol provides for accurate measurement of in-situ values of these parameters (with the possible exception of temperature), which are important geochemical data for characterization. pH and temperature measurements tend to stabilize first, and are not particularly sensitive measures of complete purging, whereas DO and turbidity will stabilize last and are better measures of sufficient purging.

Puls and Barcelona (1996) have outlined the procedural requirements of low-flow purging as follows:

- The sampling device should be placed in the middle of the well screen to prevent the entrainment of solids from the bottom of the well into the sample (similar positioning for subsequent sampling rounds is critical for comparability of data).
- Minimize disturbance of the water column in the well by installing sampling equipment carefully or using equipment dedicated to each well, and initiating pumping at a low rate.
- Employ steady pumping at a rate that maintains less than 0.1 ft of drawdown. In most formations, this will correspond to a flow rate of 0.1 to 0.5 L/min, but may be less than 0.1 L/min in silts and clays or greater than 1 L/min in coarse sands and gravels or from large diameter wells. Sevee *et al.* (2000) provides design equations that can be used for estimating the pumping rate that yields 0.1 ft of drawdown, given well size and aquifer hydraulic conductivity.
- Purging should continue until pH, temperature, conductivity, E_h , DO, and turbidity stabilize. These measurements should be made in a sealed, flow-through cell. Of these parameters, turbidity is the best parameter for measuring sufficient purging. Satisfactory purging may require removal of more than one casing-volume of water, but typically requires less than three casing volumes.

- A dedicated, pre-installed pump or tubing is recommended to minimize the time required to sample each well. Use of dedicated pumps also prevents cross contamination of wells that can result from incomplete decontamination and causes less mixing of casing water prior to purging. The cost-effectiveness of using dedicated pumps should be assessed based on site-specific sampling requirements.

Samples should be obtained from a sampling port upstream of the flow-through cell after parameter stabilization is achieved. Samples may be field-filtered if DQOs require measurement of dissolved versus mobile chemicals. Filtering should not be used to compensate for poor sampling technique, although in some cases the generation of turbidity artifacts may be unavoidable (e.g., fine-grained formation, poorly installed wells). When filtering is needed for either reason, in-line cartridge filters are recommended because they reduce handling and exposure of the sample to the atmosphere. If maintaining accurate particle-size cutoffs is a concern in filtering, a cascade system should be used (i.e., 1-micron pre-filter, followed by filtration through 0.45-micron or other smaller size filter).

In summary, the low flow protocol is preferred because it:

- typically minimizes the volume of purge water for disposal;
- provides most accurate measurements of volatile constituents;
- ensures collection of samples representative of in-situ conditions;
- collects samples containing only the mobile fraction of particulates; and
- is less vulnerable to inconsistencies among sampling staff over time.

Low flow sampling also has several disadvantages that must be kept in mind when planning sampling programs:

- higher initial capital costs, particularly if a pump is dedicated for each monitoring well;
- more time is often required to obtain a sample, which can increase total cost;
- more sophisticated equipment is used which requires more training; and
- more equipment needs to be transported to the field (e.g., conventional purging requires only a bailer whereas low-flow purging requires a pump, air cylinder, battery, or other power source).

Careful consideration of the appropriate sampling practice is critical to investigation. Traditional sampling techniques can provide inaccurate, misleading, or incomplete information relative to many aspects of geochemistry relevant for assessment. The importance of low flow sampling at sites is emphasized by Woodward (2000) who presents a case study that illustrates that many years of traditional sampling failed to support an argument that was later demonstrated relatively easily once low flow

sampling was used. In this case, traditional sampling methods indicated aerobic conditions not conducive to the degradation of the contaminants. Low-flow sampling techniques revealed that in-situ conditions were in fact anaerobic.

Modified Low Flow Protocol (low recharge wells)

Wells in low yield formations such as bedrock and clay may not be conducive to low flow purging and sampling. In these cases, pumping even at low rates may cause more than 0.1-ft of drawdown in the well or evacuate the well casing altogether. Note, however, that in these cases traditional purging is also inadequate, and it is even more important to remain cognizant of and strive to implement the goals of low flow sampling.

The practical lower limit on purge rate is a function of the casing volume, logistical constraints (time, available equipment, accessibility of the monitoring well), the required sample volume for analysis, and the tendency for sample quality to be altered as it passes through the sampling equipment. At very low pumping rates, the volume of the flow through cell must be decreased, and sample tubing length, thickness, and material may become critical. Barcelona *et al.* (1985) provide guidelines for tubing length, diameter, and thickness to minimize gas diffusion across tubing walls.

If, after consideration of these factors, it is determined that the low flow protocol is impractical, a modified low flow method should be used. Currently, there is no established protocol for sampling low recharge wells. The USEPA low flow protocol has provided guidance for low flow sampling in low permeability units and several investigators have addressed the issue of bias in VOC measurements resulting from purging of low recharge rate wells. The low flow guidance and the findings of these studies are consistent with the following modifications to the low flow protocol. These modifications have recently been endorsed by the USEPA for sampling and purging of wells that yield less than 100 mL/min at a drawdown of 0.1 m. During implementation of these methods, constant pumping with a peristaltic or bladder pump is recommended and field parameters should be measured, although it may be difficult to obtain stable measurements of certain parameters (i.e., DO, ORP, turbidity).

Method 1

The well is purged from the midpoint of the well screen at a rate no greater than 500 mL/min until the water level reaches the middle of the well screen. Pumping is ceased and the water level in the well is allowed to recover to static conditions. The well is purged a second time at a rate no greater than 500 mL/min until the water level reaches the middle of the well screen at which time pumping is ceased, this is repeated until a minimum of one casing volume is removed from the well. The well is allowed to recover sufficiently to collect the required groundwater sample from the midpoint of the screened interval, within 24 hours of the last purging event.

Method 2

This method is suggested for wells that have more than half of their casing volume of water located above the well screen. The well is purged from the middle of the well screen at a rate no greater than 500 mL/min until the water level reaches the middle of the well screen. This removes at least one-half of a casing volume of water from the well. The well is then allowed eight hours to recover, after which time a volume of water equal to the casing volume of the screened interval is removed, essentially resulting in the removal of a full casing volume during the two purging events. Directly following the second purging event, the required groundwater sample is collected from the midpoint of the screened interval. If a modified low-flow protocol is required at a site, the choice of which protocol to implement should be made based on site conditions and regulatory preferences.

Other Modifications

Other modifications of the low-flow protocol may be deemed appropriate on a site-specific basis. Large diameter wells, for example, may require exceedingly long purge times at typical low-flow rates. Methods employed to sample such wells in a cost-effective manner should consider the potential to mobilize particulates, expose the sample to the atmosphere, obtain accurate field parameter measurements, and minimize waste.

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STANDARD OPERATING PROCEDURE NO. 120

CONSTRUCTION OF MONITORING WELLS

Prepared by: D.G.L. Date: 9 February 2007

Reviewed by: Pete J. deHaan Date: 12 February 2007

Approved by: Nandha D. Date: 13 February 2007

SOP No. 120

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	2
2.1 Monitoring Well Installation	2
2.2 Well Screen and Casing.....	3
2.3 Filter Material	3
2.4 Setting Screens and Riser Casing	3
2.5 Surface Completion	6
2.6 Documentation.....	7
2.7 Cleaning of Drilling Equipment	7

STANDARD OPERATING PROCEDURE NO. 120 CONSTRUCTION OF MONITORING WELLS

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to provide instructions for monitoring well installation and construction. The field form for monitoring well completion is included with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

This SOP describes the protocol to be followed during the installation of monitoring wells, groundwater extraction and vapor extraction wells, and piezometers. Drilling and logging of soil borings for well installation will be in conformance with the standard operating procedures for the drilling and sampling of soil borings.

1.3 Equipment

The field engineer/geologist overseeing the construction of the monitoring well should have the following equipment in the field during well installation:

- field log book, pens, and well construction/completion form (included in SOP);
- weighted measuring device;
- water level tape;
- level or plumb bob;
- calculator;
- well specifications for screened interval, filter pack length and construction, pipe diameter and type, etc. (provided in the FSP); and
- appropriate Personal Protective Equipment (PPE) and air monitoring equipment per the HASP.

2. PROCEDURES

2.1 Monitoring Well Installation

An underground utility check will be performed before drilling begins. An underground utility check will, at a minimum, consist of contacting local utility alert services, if available.

The field engineer/geologist shall inventory the well construction materials prior to the start of well construction. If sufficient materials are not on-site and/or are in unacceptable condition, well construction will not begin until all appropriate materials are on-site. All proposed monitoring wells will be constructed from materials specified in the field work plan and FSP (e.g., two-inch diameter, Schedule-40 polyvinyl chloride (PVC)). All well materials shall be new and clean. Soiled materials will be cleaned prior to use, and decontaminated if there is a potential that well materials contacted contaminated surfaces.

2.2 Well Screen and Casing

The well casing and screen will generally consist of threaded stainless steel or schedule 40 (minimum) PVC pipe, although Teflon, polyethylene, steel, and polypropylene pipe are occasionally used. The casing material is defined in the FSP; however, the inside diameter of the casing should be large enough to permit unobstructed passage of an appropriate water-level probe and equipment for purging wells and water sample collection. Screen slot size specifications will be determined after filter pack specifications have been determined as discussed in Section 2.3.

All well casings and screens will be joined through threaded connections equipped with seals; solvent welds are not suitable due to the potential for contamination from the solvent glue.

The well screen will generally consist of machine-slotted PVC or wire-wrapped stainless steel screen. The screened sections will provide flow between the target zone and the well, allowing efficient well development and representative sample collection. Prior to the installation of the screen, the project geologist or engineer will determine the proper screen slot size.

2.3 Filter Material

Filter material will be well-graded, clean sand with a specific gravity of at least 2.5. The filter material will be either a standard sand gradation designed for a range of anticipated soil types or a sand gradation specifically designed to fit the soils collected from the anticipated well completion zone. If the latter approach is pursued, grain size distribution analyses will be performed on the medium planned for monitoring. The filter pack and well screen will then be designed using the methods defined in Driscoll, *Groundwater and Wells* (1986).

2.4 Setting Screens and Riser Casing

If not previously done, PPE will be donned and air monitoring will be begun per HASP requirements. Upon completion of drilling and/or geophysical logging, the boring will

be sounded with a weighted measuring tape to verify the total depth of the boring. Six inches of filter pack sand shall be poured into the boring and allowed to fall to the bottom of the boring. The boring shall be sounded after placing the sand to verify its thickness.

The well casing and well screen will then be assembled *ex situ* and lowered into the boring. If the boring is too deep to assemble *ex situ* and lower into the boring, it may be assembled in manageable lengths and each length attached as the well casing and screen are lowered into the boring. If the well casing and screen are assembled as they are lowered into the boring, extreme caution must be used to ensure materials (including the well casing and screen) do not accidentally fall down the well.

Well casing materials will be measured to the nearest 0.1 ft and steam cleaned before being used for well construction (materials in protective packaging do not require steam cleaning unless exposed to dirty or contaminated surfaces prior to installation). The bottom of the well will be fitted with a secure bottom-end cap. No PVC cement or other solvents will be used to fasten the well casing joints, well screen joints, or end caps.

Stainless steel centralizers shall be used for all sections of well in bedrock. Centralizers will be used immediately above and below the well screen and every 30 to 50 feet along the length of the casing. Centralizers need not be placed on well assemblies installed within augers or drill casings because the auger or drill casing will adequately center the well casing and screen in the borehole.

For borings drilled by the mud rotary method, potable water may be added to the drill mud and circulated in the borehole after completing the boring. Circulation will continue until the suspended sediment in the return fluid decreases. If borehole conditions are relatively stable, the mud will be thinned before the casing assembly is lowered into the specified depth. This is preferred because it reduces the potential for clogging the well screen with thick mud. Conversely, if borehole conditions are relatively unstable, the mud will be thinned after the casing is placed at the specified depth but prior to installing the annular fill materials. After installing the well

assembly, a slurry of filter sand and potable water will then be placed into the annular space.

For borings drilled using the hollow-stem auger method, the filter sand will be placed after the well assembly has been lowered to the specified depth through the augers. The augers will be incrementally raised as the filter sand is placed by free fall through the augers. Increments of one to two feet are recommended. The depth to the top of the filter pack will be measured after each increment to detect possible bridging (bridging is the interlocking of sand particles between the well and boring which results in a void in the well annulus). If bridging occurs, it will be broken by washing the filter materials into proper place with potable water, by repeatedly raising and lowering the augers slightly, or by tapping the bridge with a steel rod. The amount of water, if any, added to the borehole must be noted on the well completion form.

For monitoring wells, the filter sand will be placed in a calculated quantity sufficient to fill the annular space to a level of approximately 2 ft above the top of the well screen (the length of the filter pack will be defined in the field work plan). For extraction or pumping wells, the level of filter sand above the well screen will be based on site conditions. The depth to the top of the filter pack will be verified by measuring, using a weighted tape.

Once the depth to the top of the filter material has been verified, fine sand (choker sand) will be placed in the annular space as a transition seal between the filter material and the bentonite seal. Bentonite will be poured to fill the annular space to a minimum of two feet above the choke to seal the screening interval. If bentonite is to be placed below standing water, a high-solids bentonite grout will be pumped through a tremie pipe, or bentonite chips may be poured through the annulus (bentonite pellets may be used in place of chips only if it is certain that the coating on pellets will have no impact on groundwater or aquifer chemistry). If bentonite is to be placed above standing water, a high-solids bentonite grout should be used or bentonite chips may be placed in 6-inch lifts. Unless prohibited by well conditions, each lift should be hydrated using approximately 1 gallon of potable water per lift of bentonite chips. The completed bentonite transition seal will be allowed to hydrate for at least 30 minutes prior to

placing the grout. The depth to the top of the transition seal will be verified by measuring, using a weighted tape.

A neat cement grout, cement/bentonite grout, or high-solids bentonite grout will be placed from the top of the transition seal to the ground surface. The grout seal will be placed in hollow-stem auger borings by free fall through the augers as they are incrementally raised, or by pumping through flexible hose or tremie pipe lowered to near the bottom of the zone being grouted. The grout must be tremied if there is standing water in the augers above the transition seal. Typical specifications of grout mixtures include the following:

- neat cement grout composed of Class A, Type I Portland Cement mixed with not more than seven gallons of clean water per bag (one cubic foot or 94 pounds) of cement with a density of 15 to 16 pounds per gallon, or to manufacturer's specifications;
- bentonite-cement grout composed of powdered bentonite (less than 5% by weight) mixed at not more than eight gallons of water to the bag, with a density of 14 to 15 pounds per gallon, or to manufacturer's specifications; or
- high solids sodium bentonite grout with a minimum of 20% solids and mixed per manufacturer's specifications with water and/or other required additives.

2.5 Surface Completion

Upon completion of the well, the riser pipe will be cut cleanly so that the top of the well is level, and a mark or notch made on the top of the riser pipe identifying a measuring point for all water level measurements at the well. The well will then be fitted with a suitable slip-on cap, threaded end cap, or waterproof cap will be fitted on the top of the riser casing to reduce the potential for entry of surface runoff or foreign matter. Either a steel protective well cover (e.g., stovepipe), or a vault (e.g., roadbox) that will have a traffic-rated cover will be completed at the ground surface. All wells will be locked for security and will be designed to limit surface water infiltration. Protective well casing

and vaults shall be sufficiently large for the well cap and lock, and shall be fixed in place using cement, concrete or a similar material.

2.6 Documentation

A well construction/completion form for each well will be completed in the field by the field geologist/engineer. Well installation and construction data will be summarized in the log book. Well development notes and field measurements of water quality parameters will be summarized on corresponding well development forms.


2.7 Cleaning of Drilling Equipment

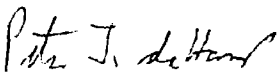
Cleaning the drill rig and associated drill equipment will follow the procedures discussed in the FSP and QAPP.


Decontamination fluid will be collected and stored properly for future disposal by the client, unless other arrangements have been made.

STANDARD OPERATING PROCEDURE NO. 130

MONITORING WELL DEVELOPMENT

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 130

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	2
2.1 General.....	2
2.2 Documentation.....	4

STANDARD OPERATING PROCEDURE NO. 130 MONITORING WELL DEVELOPMENT

1. INTRODUCTION

1.1 Overview

This standard operating procedure (SOP) describes the protocol to be followed during the development of monitoring wells. The field form for monitoring well development is included with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objectives of monitoring well development are to remove sediment that may have accumulated during well installation, to consolidate the filter pack around the well screen, and to enhance the hydraulic connection between the target zone and the well.

1.3 Equipment

The following equipment will be used during well development:

- Personal Protective Equipment (PPE) and air monitoring equipment per the HASP;
- submersible pump, peristaltic pump, and/or bailer;
- surge block;
- container for purge water (drums or fractionation tank);
- container with known volume (e.g., five-gallon bucket) for flow estimation;
- water level indicator;
- stopwatch or timer;
- clear glass jars (at least two);
- turbidity meter;
- well development record form (included in SOP);
- field log book; and
- pens.

2. PROCEDURES

2.1 General

Monitoring well development shall be performed, as soon as practical, after well installation, but not sooner than 24 hours following placement of the grout seal. Weather conditions may increase grout set time and, consequently, further delay development.

PPE will be donned and air monitoring begun per HASP requirements before the well is approached.

Development of wells shall be accomplished with a submersible pump, peristaltic pump, and/or bailer that shall preferably remain solely dedicated to that well. Bailers shall be used to develop wells only where the volume of water is so small that other development methods are clearly inappropriate. Pumps used for well development shall be periodically raised and allowed to drain back into the hole in order to induce flow out through the well screen.

A surge block may be used to flush the filter pack of fine sediment in instances where field personnel expect that development may be improved by surging. Surging will be conducted slowly to reduce disruption to the filter pack and screen. Following surging, the well will be pumped or bailed again to remove sediment drawn in by the surging process until suspended sediment is reduced to acceptable levels (see below). Water shall not be added to the well to aid in development.

A well is considered fully developed when all the following criteria are met:

- the well water is clear to the unaided eye (based on observations of water clarity through a clear glass jar) and turbidity readings have stabilized to $\pm 10\%$ over three consecutive readings;
- the sediment thickness remaining in the well is less than one percent of the screen length; and
- the total volume of water removed from the well equals five times the standing water volume in the well (including the well screen and casing plus saturated annulus, assuming 30 percent porosity) plus the volume of drilling fluid lost.

The cap and all internal components of the well casing above the water table shall be rinsed with deionized water to remove all traces of soil, sediment, and cuttings. This washing shall be conducted before and/or during development.

Non-dedicated pumps shall be decontaminated prior to use in the next well, and dedicated tubing and/or bailers shall be used during subsequent sample collection from the well.

2.2 Documentation

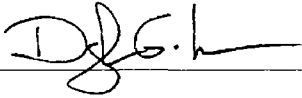
The following data shall be recorded for development:

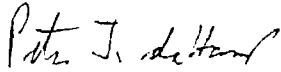
- well designation;
- date of well installation;
- date of development;
- static water level before and after development;
- quantity of drilling fluid lost during drilling;
- quantity of standing water in well and annulus (30-percent porosity of saturated annulus assumed for calculation) prior to development;
- depth from top of well casing to top of sediment inside well, before and after development;
- physical character of removed water, including changes during development in clarity, color, particulates, and odor;
- turbidity readings;
- type and size/capacity of pump and/or bailer used;
- typical pumping rate;
- estimate of recharge rate; and
- quantity of water removed and time for removal.

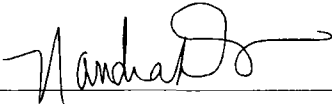
This information shall be documented on a well development form (attached).

STANDARD OPERATING PROCEDURE NO. 140

WELL ABANDONMENT

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 140

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Equipment.....	2
2. PROCEDURES	2
2.1 Removal of Well Screen and Casing.....	2
2.2 PVC Well Removal	2
2.3 Documentation.....	3

STANDARD OPERATING PROCEDURE NO. 140 WELL ABANDONMENT

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) provides instructions on the proper method for decommissioning and abandoning wells. The methods provided in this SOP are designed to prevent contaminant migration from the ground surface to the water table or between separate aquifer systems.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

The USEPA-preferred method of well abandonment requires the following steps:

1. remove well casing and screen;
2. clean out borehole;
3. backfill the cleaned bore hole with cement, bentonite grout, neat cement, or concrete; and

4. notify appropriate state agency.

1.2 Equipment

Well abandonment requires the services of a drilling subcontractor in most cases. The driller will provide the equipment need for well abandonment. A field geologist/engineer will oversee the well abandonment. The field engineer/geologist should have the following equipment:

- Personal Protective Equipment (PPE) and air monitoring equipment as specified by HASP;
- field log book;
- pen; and
- appropriate documentation (e.g., FSP, maps, HASP, and SOPs).

2. PROCEDURES

2.1 Removal of Well Screen and Casing

PPE will be donned and air monitoring begun per HASP requirements before drilling begins.

These procedures are appropriate for wells with diameters of one to four inches. This task may be accomplished by drilling over the well casing to the bottom of the borehole using a hollow stem auger. This will remove the well, grout and filter pack. A drill rig will be necessary to perform this task. The borehole shall then be cleaned by flushing with water or drilling mud. The cleaned borehole shall then be backfilled using a cement and/or bentonite grout placed using the tremie method. The top two ft of the borehole should be sealed with concrete to create a secure surface plug.

2.2 PVC Well Removal

Polyvinyl chloride (PVC) is soft enough to drill out using an auger or rotary bit, but can be difficult to remove because the PVC has a tendency to break during removal procedures. If PVC breaks when over-drilling using a hollow-stem auger, a mud rotary

or sonic drilling method should be used to remove the old well. Drilling directly down the well should be performed. A casing that is several inches larger than the well diameter and filter pack should be advanced. The well, well seal, and filter pack shall all be drilled through and removed as drill cuttings. After removal of casing materials, the well shall be flushed with drilling fluid (if using mud rotary) to remove all well cuttings, and then the boring should be tremie grouted (to within two-ft of the ground surface) and a two-foot concrete plug/surface seal should be installed. In some instances, surface protection may be specified.


2.3 Documentation

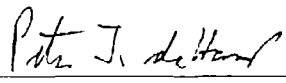
The following items will be documented in the field log book:

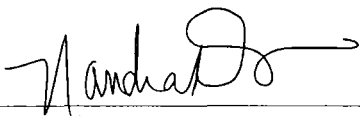
- monitoring well abandoned;
- drilling contractor;
- drilling method;
- any drilling irregularities (e.g., trouble removing well materials);
- abandonment materials; and
- start and end time.

STANDARD OPERATING PROCEDURE NO. 150

SLUG TESTS

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 150

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	2
2. PROCEDURES	2
2.1 Rising or Falling Head Tests Equipment.....	2
2.2 Rising or Falling Head Tests	3
2.3 Pneumatic Rising Head Tests Equipment.....	7
2.4 Procedure for Conducting Pneumatic Rising Head Slug Tests	9

STANDARD OPERATING PROCEDURE NO. 150

SLUG TESTS

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in conducting slug tests. This SOP details equipment and testing procedures for monitoring wells screened above and below the water table in high or low permeability confined or unconfined aquifers. This SOP conforms to “A Compendium of Superfund Field Operations Methods (EPA/540/P-87/001),” the Resource Conservation and Recovery Act (RCRA) Ground Water Monitoring Draft Technical Guidance (EPA/530-R-93-001), and other pertinent technical publications. A well inspection and slug test field form is provided with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of slug testing is to obtain an order-of-magnitude estimate of aquifer hydraulic conductivity in the immediate vicinity of the tested well. This objective requires knowledge of aquifer geology and well geometry, as well as the collection of sufficient test data to allow estimation of aquifer hydraulic characteristics. A slug test can be performed as a rising head or falling head test, and is one of several wellpoint hydraulic conductivity measurement techniques that can be employed using a single well with limited effort. Alternative wellpoint tests may be more appropriate for high yield formations, and can be conducted by extracting water at a constant rate, or maintaining the water level in monitoring well at a constant drawdown, similar to a step test.

2. PROCEDURES

Procedures for conducting three types of slug tests are described below, including:

- rising or falling head tests in wells screened below the water table;
- rising head tests in wells screened across the water table; and
- pneumatic rising head tests in highly transmissive sand and gravel aquifers.

2.1 Rising or Falling Head Tests Equipment

The following equipment is necessary to perform a rising or falling head slug test in a monitoring well:

- Personal Protective Equipment (PPE) and air monitoring equipment per the HASP;
- water level measuring device;
- bailer;
- slug bar;
- rope or wire;
- slug test data form (included in SOP);

- field log book;
- electronic data logger;
- pressure transducer and conductor cable;
- stop watch or watch with a built-in timer;
- duct tape; and
- well completion diagrams.

The slug bar may be constructed of solid or hollow plastic, such as PVC or metal (e.g., aluminum or steel depending upon the chemical environment in the well). If hollow, the slug bar will be filled with silica sand or other inert material to add weight. The slug bar should be of sufficient size to cause a minimum of two ft of displacement in a well. For a two-inch diameter well, the slug bar should be no more than 1.5 inches in diameter and a minimum of 3.6 ft long. For a four-inch diameter well, the slug bar should be no more than 3 inches in diameter and a minimum of 3.6 ft long. The slug bar should be securely fastened to a nylon rope or wire.

A standard sampling or well development bailer may be used in place of the slug bar, as long as the volume of water displaced by the bailer will be sufficient to change the water level in the well a minimum of two ft. If the bailer is to be used for a falling head test, it should be filled with analyte-free water so that the bailer will not have any buoyancy.

2.2 Rising or Falling Head Tests

The following procedure should be utilized for conducting a falling head slug test. The test should not be performed in any well where the screen extends above the water table.

1. Note the physical condition of the well, including damage, deterioration, and signs of tampering.
2. Don PPE per the HASP. Perform air monitoring per the HASP. Open the well cap. Note any unusual odors, sounds, or difficulties in opening the well.
3. Lower a decontaminated water level measuring device into the well to determine the static water level.

4. Measure the depth to the bottom of the well and the inside diameter of the well casing.
5. If using a pressure transducer connected to a data logger, lower the pressure transducer into the well to a sufficient depth in the well so that the transducer will be below the maximum depth reached by the slug bar.
6. Secure the pressure transducer to the side of the well using duct tape. The transducer cable should lie flat along the side of the well riser, so that disturbance by the slug bar will be minimized. Do not bend the transducer cable or a kink will develop in the cable that will cut off the pressure equalization vent tube in the cable, which will prevent the transducer from operating.
7. Allow the pressure transducer temperature to equilibrate for a minimum of 15 minutes before connecting it to the data logger and starting the test. Also allow the water level in the well to recover to static level after placement of the pressure transducer prior to starting the test.
8. Determine the distance from the top of the well riser to the water surface in the well and add one foot to this length. The resulting length is the amount of wire or rope needed so that the slug bar or bailer will be submerged a minimum of one foot when it is placed in the well. A loop should be placed in the rope or wire at this length and a strong metal rod or wooden stick placed and secured through the loop. If the bottom of the well is less than this length added to the length of the slug bar or bailer, the length of the rope or wire should be adjusted so that the slug bar will be no less than one foot above the top of the pressure transducer when the bar is dropped in the well.
9. If using a data logger, program it to record logarithmically, with a maximum time interval of no more than one minute between readings. Set the data logger to record relative change in head only, not absolute head.
10. If depth readings are to be recorded manually (this procedure is recommended only in aquifers suspected of having low hydraulic conductivity, less than five ft per day), readings should be taken every ten seconds for the first minute of the test, every 30 seconds for the first five minutes and every minute until ten minutes. Thereafter, readings may be taken every five minutes for the duration

of the test. If the well has not recovered within one hour, readings may be taken every 0.5 hour until six hours and at one hour intervals thereafter. This process will require two people during the first ten minutes of the test, a person to act as time keeper/data recorder, and a person to measure depth to water.

11. Place the slug or bailer in the well until the bottom of the displacement device is no more than six inches above the water level in the well. The person holding the device should be holding the rope or wire by the rod or stick.
12. To start the test, the person holding the slug bar will signal the person operating the data logger and rapidly lower the device into the well until the stick or rod is resting on the well riser. **The slug bar should not be dropped.** The data logger is started as soon as the slug bar is lowered.
13. The test will be run until the well has recovered to 90 percent of static water level. If 90 percent recovery has not occurred within 12 hours, the test may be stopped. Field conditions and time constraints may warrant stopping the test in less than 12 hours.
14. All equipment (pressure transducer and cable, water level measurement device and slug bar or bailer) shall be decontaminated before repeating the test in another well.
15. Download the data logger to a computer or to hard copy to ensure that the data is not inadvertently lost. If the data were recorded manually, calculate the relative change in head by subtracting the recorded depths to water from initial static water level and record the absolute value of that change, for each time-depth data pair.

The following procedure should be utilized for conducting a rising head slug test. Note that the test may be started after completion of a falling head test in a well screened below the water table (described previously). The steps are essentially the same as those for a falling head test, except that the test is started only after a displacement device has been placed in the well and the water level in the well has recovered back to static conditions. If this test is performed after a falling head test, begin with step 12.

1. Note the physical condition of the well, including damage, deterioration, and signs of tampering.
2. Unlock the protective cap on the well.
3. Don PPE per the HASP. Perform air monitoring per the HASP. Open the well cap. Note any unusual odors, sounds, or difficulties in opening the well.
4. Lower a decontaminated water level measuring device into the well to determine the static water level.
5. Measure the depth to the bottom of the well and the inside diameter of the well casing.
6. If using a pressure transducer connected to a data logger, lower the pressure transducer into the well to a sufficient depth in the well so that the transducer will be below the maximum depth reached by the slug bar.
7. Secure the pressure transducer to the side of the well using duct tape. The transducer cable should lie flat along the side of the well riser, so that disturbance by the slug bar will be minimized. Do not bend the transducer cable or a kink will develop in the cable that will cut off the pressure equalization vent tube in the cable, which will prevent the transducer from operating.
8. Determine the distance from the top of the well riser to the water surface in the well and add one foot to this length. The resulting length is the amount of wire or rope needed so that the slug bar or bailer will be submerged a minimum of one foot when it is placed in the well. A loop should be placed in the rope or wire at this length and a strong metal rod or wooden stick placed and secured through the loop. If the bottom of the well is less than this length added to the length of the slug bar or bailer, the length of the rope or wire should be adjusted so that the slug bar will be no less than one foot above the top of the pressure transducer when the bar is placed in the well. Slowly lower the slug into place; this will raise the water level in the well.
9. Allow the pressure transducer to temperature equilibrate a minimum of 15 minutes before connecting it to the data logger and starting the test. Also allow

the water level in the well to recover to static level after placement of the pressure transducer and slug prior to starting the test.

10. If using a data logger, program it to record logarithmically, with a maximum time interval of no more than one minute between readings. Set the data logger to record relative change in head only, not absolute head.
11. If depth readings are to be recorded manually (this procedure is recommended only in aquifers suspected of having low hydraulic conductivity, less than five ft per day), readings should be taken every ten seconds for the first minute of the test, every 30 seconds for the first five minutes and every minute until ten minutes. Thereafter, readings may be taken every five minutes for the duration of the test. If the well has not recovered within one hour, readings may be taken every 0.5 hour until six hours and one hour thereafter. This process will require two personnel during the first ten minutes of the test, a person to act as time keeper/data recorder and a person to measure depth to water.
12. To start the test, the person holding the rope or wire attached to the slug bar will signal the person operating the data logger and rapidly remove the device from the well. The slug bar should be removed rapidly but smoothly so that water sloshing in the well is minimized. The data logger is started immediately when the slug bar is removed.
13. The test will be run until the well has recovered to 90 percent of static water level. If 90 percent recovery has not occurred within 12 hours, the test may be stopped. Field conditions and time constraints may warrant stopping the test in less than 12 hours.

2.3 Pneumatic Rising Head Tests Equipment

The following equipment should be utilized when conducting a pneumatic rising head slug test:

- PPE and air monitoring equipment per the HASP;
- water level measuring device;
- slug test data sheet;
- field log book;

- electronic data logger;
- pressure transducer(s) and conductor cable;
- stop watch or watch with a built-in timer;
- duct tape;
- pressure-tight “tree” assembly;
- short length (six inches) of flexible rubber hose whose inside diameter is the same as the outside diameter of the well riser;
- two 2- or 4-inch diameter hose clamps; and
- compressor or compressed air tank with hose and appropriate adapters.

The pressure-tight “tree” assembly is a device placed on the top of the well that will accomplish the following (a “tree” consist of a several tees in series with the top leg of the tee connected to a pressure source, a side leg of the tee connected to a pressure relief valve, and another leg used to run the pressure transducer cable down the well):

- form a pressure seal between the well and the atmosphere;
- allow the injection of compressed air into the well via an air hose connected to a compressor or compressed air tank;
- provide a pressure-tight passage for a pressure transducer cable and a water level meter; and
- allow for rapid well depressurization.

If the top of the riser is threaded, the device may be screwed onto the riser, if the threads are wrapped with Teflon® tape. If the threaded end of the riser has been cut off, a slip coupling will need to be placed over the base of the tree and the top of the riser. A small length of flexible rubber hose the same inside diameter as the outside diameter of the coupling will be slipped over the coupling and secured in place with tightly closed hose clamps to form a pressure tight seal between the riser and the well.

The simplest method for providing access for the pressure transducer cable and the water level meter is to use a standard large diameter laboratory black rubber cork with a hole through the cork's axis that has been slit half way through along that axis. The cork can be firmly placed into the port form a pressure tight seal.

The tree will have a standard ball valve with an inside valve orifice diameter no less than the diameter of the well riser. In addition, a standard swage-lock fitting or quick-connect coupling will be attached to the side of the tree to act as a compressed air inlet port.

2.4 Procedure for Conducting Pneumatic Rising Head Slug Tests

The following procedure should be used for conducting a pneumatic rising head slug test. The test may not be run in any well screened across the water table. This method is well suited to wells screened in highly transmissive deposits because the stress can be applied nearly instantaneously. In such tests, water level variation in the monitoring well may be oscillatory, as insufficient damping of inertial forces occurs in the formation. Analysis of oscillatory data is possible using methods such as described by Van Der Kamp (1976) and Kipp (1985).


1. Note the physical condition of the well, including damage, deterioration, and signs of tampering.
2. Unlock the protective cap on the well.
3. Don PPE per the HASP. Perform air monitoring per the HASP. Open the well cap. Note any unusual odors, sounds, or difficulties in opening the well.
4. Check for any holes in the side of the riser. The test cannot be conducted in any well that is not air tight.
5. Lower a decontaminated water level measuring device into the well to determine the static water level.
6. Measure the depth to the bottom of the well and the inside diameter of the well casing.

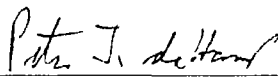
7. Install the test tree to the top of the well, either by screwing it in to existing threads or by using a slip coupling adapter. Make sure the seal to the riser head is pressure tight.
8. Lower the pressure transducer into the well through a port in the tree to at least ten ft below the water table. The pressure transducer should be rated no less than 30 pounds per square inch.
9. Allow the pressure transducer to temperature equilibrate a minimum of 15 minutes before connecting it to the data logger and starting the test.
10. Turn on and lower the water level indicator into the well through the top of the tree to five ft below the water table. If the water table is less than five ft from the top of the well screen, place the indicator no less than two ft above the screen. Turn off the indicator.
11. Secure the transducer cable and the water level meter and tape in place to the top of the tree with a cork as described previously. Insert the transducer cable into the hole in the rubber lab cork via the slit and place the water level indicator tape flat in the slit. Place the cork firmly in the top of the tree so that no gaps are left in the cork. Place small strips of duct tape over the assembly to ensure that the seal is air tight. During this procedure, do not bend the transducer cable or a kink will develop in the cable that will cut off the pressure equalization vent tube in the cable. Such kinks will prevent the transducer from operating.
12. Connect the pressure transducer to the data logger and program the data logger to record logarithmically, with a maximum time interval of no more than one minute between readings. Set the data logger to record relative change in head only, not absolute head.
13. Connect the air hose to the compressed air supply or compressor and the tree. Make sure the ball valve is securely closed.
14. Turn on the water level indicator and start feeding compressed air in to the well. When the water level in the well has been depressed sufficiently, the water level indicator submergence tone will stop sounding. Allow the well to equilibrate with the depressed water level (i.e., seal the well and allow it to stand for several hours or overnight).

15. Open the ball valve and activate the data logger simultaneously. The ball valve should be opened as quickly as possible.
16. In highly permeable aquifers the water level in the well should recover to pre-test static water levels within a few seconds. Full recovery should be accomplished in no more than one minute. If the data logger is the type that cannot be read until the test has run at least ten minutes, do not stop the test until a minimum of 90 percent recovery can be confirmed by interrogating the data logger.
17. All equipment (i.e., pressure transducer and cable, water level measurement device and displacement device) should be decontaminated before repeating the test in another well.
18. Download the data logger to a computer or to hard copy to ensure that the data are not inadvertently lost.

STANDARD OPERATING PROCEDURE NO. 160

GENERAL PUMPING TEST PROCEDURES

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 160

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	3

STANDARD OPERATING PROCEDURE NO. 160 GENERAL PUMPING-TEST PROCEDURES

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods and general procedures for conducting pumping tests in monitoring wells. Additional guidance can be found in Suggested Operating Procedures for Aquifer Pumping Tests (Paul Osborne, 1993, EPA/540/S-93-503). A step drawdown test field form is provided with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objectives of pumping tests include identifying aquifer properties of recharge, drawdown, storativity, transmissivity, specific and sustained yield, and aquifer boundaries. Knowledge of these aspects is essential to aid in the understanding of aquifer characteristics for the configuration of remediation or ground water supply systems.

1.3 Equipment

The following equipment may be used during the conduct of an aquifer pumping test:

- field log book or pump test log included in SOP;
- water level indicators;
- pressure transducers;
- data logging equipment;
- recording rain gauge (or obtain hourly data for local weather station);
- field printer;
- laptop computer;
- duct tape;
- deionized water;
- submersible pump with flow regulator and foot valve;
- flow meter/totalizer;
- generator or other power source;
- heavy-duty extension cords;
- polyethylene sheeting;
- frac tank, Baker tank, or other storage vessel, if water requires containment;
- Personal Protective Equipment (PPE) and air monitoring equipment per HASP;
- portable two-way radios;
- well completion logs;
- well keys;
- flow meter/graduated bucket; and
- stopwatch.

2. PROCEDURES

The following general procedures should be used for conducting a pumping test. Alterations of these general procedures may be necessary in order to accommodate site specific conditions and data requirements.

Aquifer pumping tests should follow the set-up procedures listed below in order to consistently record the desired data as accurately as possible.


1. Determine the appropriate lengths of transducer cables based on the distances from pumping to observation wells. Based on the well geometries, determine the appropriate pressure-rated transducer, number of logging channels needed, required pump hosing length, pump capacity and type, and minimum and maximum anticipated pumping rates. Identify the test control location and create a pre-test schematic of where the wells are, depth of transducer and pump settings, where the water will be discharged or containerized, and how the test can be implemented efficiently before going into the field. If sealed (unvented) transducers are used, an additional transducer will be required to monitor and correct for atmospheric pressure. If vented transducers are used, variations in atmospheric pressure will automatically be accounted for; however, if the tested aquifer is susceptible to atmospheric pumping, monitoring of atmospheric pressure may be required to help interpret water level data.
2. Conduct decontamination of all downhole test equipment and wrap all equipment in polyethylene sheeting or bags. These should be dedicated and labeled for the intended wells.
3. After donning PPE and performing any required air monitoring per the HASP, measure water levels in all of the wells to be monitored during the test. Record the water levels in the logbook or on the pump test log. It is recommended that the water levels be monitored for a period of time prior to the test to identify any trends of rising or falling water levels due to nearby supply wells, tidal influence, or surface water bodies. A typical pre-test monitoring period is two to four weeks. If possible, the test should not be initiated within several days of large rainfall event (past or predicted).

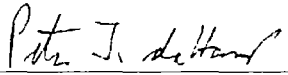
4. Set and secure the pump in the pumping well at the planned depth and allow for stabilization of the displaced water level caused by insertion. The generator should be filled with gasoline at a remote down-wind location and extension cord run to this location. Record the pump depth in the log book or on the pump test log. Monitor the water level in the pumping well to ensure that static levels are attained.
5. Secure the transducers with duct tape in the desired wells at the planned depths as identified in the pre-test schematic. Set all transducers in the wells for a minimum of two hours to allow for reaching equilibrium with ground water temperature and for cables to stretch fully. The transducer in the pumping well should be set above the pump. Run all of the transducer cables to the test control location and connect them to the data logger in the desired channel(s). Record the transducer depths in the logbook or on the pump test log.
6. While the transducers are stabilizing, programming of the data logger for each channel should be completed with the specific parameters for each transducer. Scale factors, linearity, offset, well identification, reference level, and type of reading (surface or top of casing) should be selected. These parameters are specific to each transducer and data logger and are usually clearly identified on the wheel and cable for each transducer. *After programming, each transducer should be tested for accuracy by raising it a known distance and verifying that the change in measured water level corresponds with this distance. If a long term pumping test is conducted (i.e. several weeks) checking transducers in this manner once per week is warranted.*
7. The data logger should be programmed to collect readings at the desired interval(s) for the entire duration of the test including recovery. The test should be programmed to allow for logging of water levels during the drawdown and recovery stages using the logarithmic option recommended with most data loggers. The actual log scale can also be modified to suit the needs of the test, if desired. The data logger should be programmed to start prior to initiation of pumping the well (but not so early that the recording interval is too long when pumping begins). Record the programmed duration in the log book or on the pump test log.
8. Once the test equipment is ready, the entries, well identifications, and parameters for each channel should then be double checked for accuracy. The connections to all channels should be checked by communication with each individual transducer.


9. The startup of the pump should be synchronized with the logging of water level data. The rate of pumping should be set at the desired rate as determined by an earlier step test. The rate should be stabilized as quickly as possible to promote accurate data analysis. Direct the discharge to the appropriate containers, if required, or to a location outside of the anticipated cone of influence. The pumping rate should be measured and recorded routinely (using a flow meter and/or a bucket test) during initial pumping to confirm that the rate is stable. All adjustments to the rate should be recorded. Record the actual start time and pumping rate of the test in the logbook or on the test log.
10. Monitor the channels of the data logger to read the transducers. Look for drawdown in the pumping well to confirm operation. Monitor the transducers in the observation wells to confirm their operation. Manual measurement of the water levels should be performed periodically to confirm the accuracy of the transducer data, typically several times during the first day, daily for several days, and weekly thereafter.
11. If a recovery test is also planned, re-program the data-loggers to begin a new logarithmic data collection cycle, shut down the pump, record the time and allow the water level in the pumping well and nearby monitoring wells to recover to 90 percent of static levels.
12. Once the test is completed, remove and decontaminate all downhole equipment.

STANDARD OPERATING PROCEDURE NO. 200

SURFACE SOIL SAMPLING

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 200

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION.....	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	2

STANDARD OPERATING PROCEDURE NO. 200 SURFACE SOIL SAMPLING

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the logistics, collection techniques, and documentation requirements for collecting surface soil samples. The soil sampling record to be used during field activities is provided with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of surface soil sampling (soil samples between ground surface and 6 to 12 inches below land surface) is to obtain a representative sample of soil for laboratory analysis of contaminants of concern at a given site. This objective requires that the sample be both free of unsuitable material and be of sufficient quantity and quality for analysis by the selected analytical method.

1.3 Equipment

The following equipment is needed for surface soil sampling:

- Personal Protective Equipment (PPE) and air monitoring equipment as specified in the HASP.
- Sample containers as specified in the FSP and QAPP. Note that samples that are to be analyzed for volatile organic compounds (VOCs) will be collected by the USEPA 5035 Method using the following glassware: one (1) 40 mL VOC vial pre-preserved with 15 mL of methanol, and two (2) 40 mL VOC vials pre-preserved with 5 mL of sodium disulfate. All samples submitted for VOC analysis will also include one small (40 mL to 4 oz) container, to allow the laboratory to record the moisture/dry-weight characteristics.
- Wooden stakes and spray paint (highly visible) or survey pins.
- Field log book and soil sample form (included in SOP) per FSP requirements.
- Sample bottle labels/tags.
- Chain-of-custody forms.
- Hand auger, if surface soil penetration is difficult.
- Stainless steel spoon.
- Stainless steel mixing bowl.
- Disposable syringe for VOC sampling.
- Digital scale (accurate to +/- 0.1 grams).
- Indelible marking pens.

2. PROCEDURES

The following procedure should be used for surface soil sampling.

1. Don PPE and begin air monitoring per the HASP.

2. All surface debris should be removed prior to sampling including wood, paper, sod, gravel, and trash. Identify the sample location and mark with a stake, flagging, or similar marker.
3. Collect the soil using a stainless steel shovel, hand auger, trowel and/or spatula. Avoid collection of larger pieces of material (e.g., cobbles, larger rocks). If a matted root zone is present at the sample location, it should be removed prior to sample collection.
4. A pre-cleaned stainless steel spoon or spatula should be used to take the soil sample and fill the sample containers except in the case of a sample for VOC analysis, which is collected using an open-barrel disposable syringe. Care should be taken to avoid sampling anything but soil. Stones, gravel, or vegetation should be removed from the sample since these materials will not be analyzed.
5. For VOC analysis prior to collecting the sample, USEPA Method 5035 specified preservative (5 mL sodium bisulfate for low level analysis and 15 mL methanol for high level analysis) will be added to sterilized 40 mL containers. Each pre-preserved container will then be weighed prior to sample collection, and the container/preservative weight will be recorded on the chain of custody. A digital scale capable of +/- 0.1 gram(s) accuracy will be used to weigh the sample containers in the field.
6. If a sample for VOC is desired it will be collected first using an open barrel, disposable syringe. VOC samples should **never** be homogenized or composited.
7. For a Low Level Analysis the soil will be extruded into a prepreserved VOC vial containing a stir bar, sodium bisulfate (5 mL) and distilled water.
8. If the sample is collected for high level volatile analysis, the sample will be extruded into a VOC vial containing "Purge and Trap" grade methanol (15 mL).
9. The syringe will be filled with undisturbed soil of the following approximate volumes: 5 grams of soil for low-level analysis (added to the soil of sodium bisulfate); and/or 15 grams of soil for high level analysis (added to the 15 mL of methanol).
10. Any particles of grains present on the container rim or cap will be removed to ensure an adequate seal of the vial. The VOC vial will be capped quickly and labeled/tagged with sample identifications, date, and time of collection. The

container/preservative/sample will then be weighed, and the post-collection weight will also be recorded on the chain of custody. The objective sample weights (5 g for low-level analysis, and 15 g for high level analysis) will be achieved (+/- 10%) with the use of the digital scale. Should insufficient sample volume be added to the preserved container, a stainless-steel spatula will be used to add a small portion of sample until the target weight is achieved (or exceeded within 10%).

11. In the event that a field screening technique (e.g., PID/FID instrument reading, visual staining of the soil, or olfactory observation) indicates the presence of VOCs or hydrocarbons, note the observations or instrument readings in the field logs.
12. Collect additional material for the remaining parameters by collecting the sample with the stainless steel spoon and transferring the soil into a stainless steel bowl. Homogenize the sample by mixing the sample within the bowl using the stainless steel spoon prior to filling the remaining sample containers.
13. Record the sample location, identification, and time in the field logbook. Complete the sample log sheet with the following:
 - sample identification number;
 - sample location (sketch of the sample point);
 - time and date sample was taken;
 - personnel performing the task;
 - visual description of the sample;
 - brief soil description (color, texture, appearance);
 - weights of preserved VOC containers before and after sample collection; and
 - any other pertinent observations.

After the samples have been collected, the sampling location will be marked with wooden stakes colored with highly visible spray paint and labeled/tagged with the location identification in order to survey the sample location.


All samples will be immediately placed on ice (preferably double-bagged wet ice packs) to remain at 4°C ($\pm 2^{\circ}\text{C}$) prior to and during shipment to the laboratory. The sample

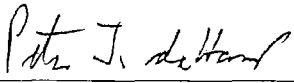
containers will be stored in a cooler until further processing. Refer to the Standard Operating Procedure 410 for sample shipping.


Refer to the FSP or QAPP for equipment decontamination procedures.

STANDARD OPERATING PROCEDURE NO. 210

**SOIL DESCRIPTION
VISUAL - MANUAL PROCEDURE OF THE
UNIFIED SOIL CLASSIFICATION SYSTEM**

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 210

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION.....	1
1.1 Overview.....	1
1.2 Objective.....	2
1.3 Equipment.....	2
2. PROCEDURES	3
2.1 General.....	3
2.2 Color	3
2.3 Density	4
2.4 Moisture Content	4
2.5 Geologic Modifiers	5
2.6 Major/ Minor Constituents.....	6

STANDARD OPERATING PROCEDURE NO. 210
SOIL DESCRIPTION
VISUAL - MANUAL PROCEDURE OF THE
UNIFIED SOIL CLASSIFICATION SYSTEM

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the method for describing soil samples in test pits, soil borings, and soil grab samples. The SOP conforms to ASTM Standard D 2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) and other pertinent technical publications.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of soil sample description is to provide consistent geological information useful for the purpose of hydrogeological or geotechnical evaluation of a site. The Unified Soil Classification System (USCS) is the suggested classification method.

1.3 Equipment

The following equipment may be necessary during soil description activities:

- sand grading chart;
- field log book or forms as required by related SOPs;
- pocket knife, spoon, small spatula;
- folding ruler or yard stick;
- portable table;
- polyethylene sheeting;
- hand lens;
- deionized water in squeeze bottle;
- required personal protective equipment (gloves, boot, eye wear, hard hat, etc.);
- Personal Protective Equipment (PPE) and air monitoring equipment as required by HASP;
- duct tape; and
- boring logs (if applicable).

2. PROCEDURES

2.1 General

The general description of a soil sample should be in the following order:

1. color;
2. density;
3. moisture content;
4. geologic modifiers or classifications;
5. major constituent – capitalized;
6. minor constituent(s); and
7. geologic description (in parentheses).

Example: Tan, loose, wet, stratified, medium SAND, little fine sand, trace coarse sand, trace silt (Till).

Before beginning, ensure that PPE has been donned and air monitoring is being performed per the HASP. When logging a soil sample collected from a split spoon where more than one soil type is present, describe each one separately, using additional line(s) on the boring log form. Start the description from the top of the split spoon, and log each change in stratigraphy in sequence to the bottom of the spoon. Provide an interval or length (i.e., 0-0.5 ft.) at the beginning of each separate sequence description, followed by a colon. Draw a line below the bottom of the complete sample description.

2.2 Color

The main color value should be stated, along with an appropriate modifier. Examples include: light brown, dark brown, reddish brown, and brown. The presence of mottling should be included in the description, where present.

Example: Gray, slightly mottled, dense, damp, poorly sorted angular fine to medium SAND, some silt, trace angular coarse sand, trace clay (lodgement glacial till).

2.3 Density

In borings, density should be based on the sum of the middle two 6-inch blow counts of a two-ft split spoon or the last two 6-inch blow counts of an 18-inch split spoon. Professional judgement should be used when applying the density modifier. If high blow counts are due to the presence of a cobble, boulder or large piece of gravel that impedes forward progress of the split spoon, density should be based upon the character of the material in the split spoon, if any, or omitted from the description. A notation should be made in the sample description when this situation occurs. Appropriate modifiers are described in the following table.

<u>Granular Soils</u>		<u>Cohesive Soils</u>	
Blows/ft	Density	Blows/ft	Density
0-4	Very loose	<2	very soft
4-10	Loose	2-4	Soft
10-30	medium dense	4-8	medium stiff
30-50	Dense	8-15	Stiff
>50	Very dense	15-30	very stiff
		>30	Hard

In test pits, density is subjective and should be based upon the ease of excavation. The above adjectives for granular and cohesive soils should be used in the description.

2.4 Moisture Content

Moisture content should be described using the following modifiers:

- **dry** - no moisture;
- **damp**- very slight moisture content, no visible water droplets;
- **moist** - very slight moisture content, soils will not stick together;

- **wet** - enough moisture for soils to stick together; or
- **saturated** - water dripping from sample; soils below the water table.

2.5 Geologic Modifiers

Sedimentological descriptions aid in the geologic classification of a soil material. Only insert geologic modifiers when present.

Stratification: Note the presence and thickness of alternating layers of non-cohesive materials of different grain sizes and/or color with layers ***at least 6 mm*** thick.

Lamination or Varves: Note the presence and thickness of alternating very thin layers of fine materials or color, such as silt and clay, with layers ***less than 6 mm*** thick.

Sorting: A geological term used to describe how close in size the grains in a sample are to each other. For example, a well sorted sample contains grains of similar size; a poorly sorted sample contains grains of many sizes.

Angularity or Rounding: Geological terms that are used to describe the general appearance of visible grains in the soil sample. Useful in determining the origin and depositional environment of a material. Water transported materials may be rounded. Glacial tills will be more angular. The following terms describe differing degrees of angularity:

- **angular** – particles have sharp edges and relatively plane sides with unpolished surfaces;
- **subangular** – particles are similar to angular description but have rounded edges;
- **subrounded** – particles have nearly plane sides but have well-rounded corners and edges; and
- **rounded** – particles have smoothly curved sides and no edges.

Shape: A term used to describe the shape of gravel, cobbles, and boulders. Terms are as follows where the particle shape shall be described where the length, width, and thickness refer to the greatest, intermediate, and least dimensions of a particle:

- **flat** – particles with width/thickness > 3 ;
- **elongated** – particles with length/width > 3 ; or
- **flat and elongated** – particles meet criteria for both flat and elongated.

Odor: Describe the odor if organic or unusual. Soils containing a significant amount of organic material have a distinct odor of decaying vegetation. Always utilize appropriate breathing zone air monitoring equipment as specified in the site-specific HASP.

Cementation: Describe the cementation of intact coarse-grained soils as follows:

- **weak** – crumbles or breaks with handling or little finger pressure;
- **moderate** – crumbles or breaks with considerable finger pressure; or
- **strong** – will not crumble or break with finger pressure.

Identification of Peat: A sample composed primarily of vegetable tissue in various stages of decomposition that has a fibrous to amorphous texture, usually a dark brown to black color, and an organic odor. When present the sample shall be designated as highly organic soil.

2.6 Major/ Minor Constituents

Grain-size Scales: Grain size classification should be based on an accepted classification system, such as the USCS. The predominate grain size should be listed in the soil description in all capital letters, selected from the following:

- boulder: 300 mm;
- cobble: 75 - 300 mm;
- coarse gravel: 19 - 75 mm;

- fine gravel: 4.75 - 19 mm;
- coarse sand: 2.0 - 4.75 mm;
- medium sand: 0.425 - 2.0 mm;
- fine sand: 0.075 - 0.425 mm;
- silt: 0.002 - 0.075 mm; or
- clay: <0.002 mm.

Proportions: For geologic description, proportions of grain sizes will be based upon the following nomenclature:


- trace: 0-10%;
- little: 10-20%;
- some: 20-35%; or
- and: 35-50%.

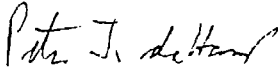
The major soil sample constituent is always capitalized and listed first. Minor constituents also include ancillary materials, such as mica flakes, dark minerals, or naturally occurring organic matter, such as humus, peat, or other vegetative material.

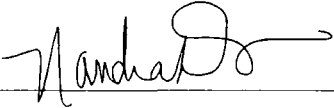
Geologic Description: Where possible based on existing site data, local research, or geologic understanding of the local region, include a geologic description of the sample. Examples include till, fluvial, glaciofluvial, fill material, or Lowell Formation. Do not utilize geologic description if not certain.

STANDARD OPERATING PROCEDURE NO. 220

TEST PIT LOGGING

Prepared by:  Date: 9 February 2007

Reviewed by:  Date: 12 February 2007

Approved by:  Date: 13 February 2007

SOP No. 220

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	2

STANDARD OPERATING PROCEDURE NO. 220 TEST PIT LOGGING

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for completing and logging test pits during field investigations at hazardous and non-hazardous waste sites. This procedure is consistent with “A Compendium of Superfund Field Operations Methods (EPA/540/P-87/001)” and other pertinent technical publications.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objectives of completing test pits can include: (i) document subsurface conditions; (ii) investigate anomalous magnetic readings; (iii) observe subsurface geology; (iv) identify the vertical extent of contamination; (v) confirm depth to bedrock; (vi) complete drum removal

activities: (vii) conduct percolation tests; (viii) obtain subsurface soil samples; (ix) delineate buried waste; and (x) identify potential subsurface conduits for ground water flow and potential contaminant migration.

1.3 Equipment

The following list of equipment includes the necessary items to be used by field personnel during test pit excavations. Subcontractor personnel typically provide and operate all excavation and steam cleaning equipment. Site-specific conditions may warrant the use of additional or deletion of items from this list.

- electronic water level indicator;
- measuring tape with weight (0.1 foot increments);
- appropriate personal protective equipment (PPE) (e.g., hardhat, gloves, eyewear, tyvek suits, boots, etc), as required by the HASP;
- air monitoring instruments as required by HASP;
- field log book;
- test pit log sheets (included in SOP);
- oil/water interface probe; and
- camera.

2. PROCEDURES

The following procedures should be used during test pitting. Procedures may vary depending on the objectives, equipment used, excavation requirements, sampling strategy, and contaminants present at the site. Site-specific conditions may warrant the use of stringent air monitoring, PPE and potentially substantial access constraints. These are defined in the HASP.

1. Utility clearance will be performed prior to test pit digging.

2. The scope of the investigation, objectives, potential contaminants, and HASP should be reviewed with all subcontractor personnel prior to initiation of the test pitting activity. All intended hand signals to be used during the excavation should be reviewed and understood between the personnel directing the operation and the equipment operator. One individual will be designated to direct the operator and record the geology and observations. The second individual will conduct continuous air monitoring and recording, photography, and sample collection, storage and documentation. All individuals will don the necessary PPE per the HASP prior to digging.
3. Initiate the excavation in approximate one- to two-foot loose lifts. Observations of visual contamination, buried containers, or potential conduits should be recorded and operations suspended while photographs and measurements of interest within the pit are made and documented.
4. Once the excavation has been completed to the desired depth, the soil should be logged as described in SOP No. 210. If samples from specific layers for geologic description are desired, the bucket should be used to obtain samples from the edges of the pit in the desired location.
5. The dimensions of the final test pit should be measured and recorded. A sketch of the test pit and any unusual features should be completed on the test pit log sheet. Photographs of at least one side of the pit and any features of interest exposed in the pit should be taken and recorded in the field log book. The depth to water should be measured from a location on the side of the pit at the original grade.
6. Material within the pit desired for laboratory analysis should be obtained with the excavator bucket. Samples for volatile organic analysis should be collected immediately from available material below the surface of the excavated material within the bucket. Additional aliquots for other analyses should then be withdrawn from the center of the bucket, homogenized in a stainless steel bowl, and placed in the required sample jars. All sample jars should be pre-labeled, wiped off, documented, and stored.
7. Backfill the excavated soil and return the excavated area to the original grade. Make certain the excavator operator compacts the backfilled soil with the

excavator bucket and does not leave any surface holes or other hazards when completed.

8. Stake, label, and flag the test pit location for future reference or surveying.

STANDARD OPERATING PROCEDURE NO. 230

SOIL AND ROCK BORING

Prepared by: D.G.H. Date: 9 February 2007

Reviewed by: Pete J. deHaan Date: 12 February 2007

Approved by: Nandha D. Date: 13 February 2007

SOP No. 230

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
2. PROCEDURES	2
2.1 Predrilling Requirements	2
2.2 Test Boring Method.....	3
2.2.1 Wash Boring	3
2.2.2 Rotary Drilling.....	4
2.2.3 Auger Borings.....	4
2.3 Borehole Stabilization	5
2.3.1 Casing	5
2.3.2 Drilling Mud	6
2.3.3 Hollow-Stem Augers	7
2.4 Borehole Cleaning	7
2.5 Logging Bedrock Cores.....	10
2.5.1 Wireline Drilling.....	12
2.5.2 Oriented Core.....	13
2.5.3 Shotcore Drilling	13
2.5.4 Preservation of Rockcore.....	14
2.6 Photographing Soil and Rock Samples from Borings	15
Attachment A Boring Log	
Attachment B Rock Core Log	

STANDARD OPERATING PROCEDURE NO. 230 SOIL AND ROCK BORING

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for recording subsurface conditions in soil borings during site hydrogeological and geotechnical investigations. The SOP conforms to “A Compendium of Superfund Field Operations Methods (EPA/540/P-87/001)” and other pertinent technical publications. The lithologic log field form to be used during soil and rock boring activities is provided with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of soil and rock borings is to provide samples for description and characterization of subsurface conditions, and obtain samples for geotechnical and/or

chemical analyses, often prior to installation of a monitoring well. This objective requires the use of consistent procedures for documenting observations and collecting samples.

2. PROCEDURES

2.1 Predrilling Requirements

When conducting borings in an industrial facility, the project or field engineer/geologist must contact all utilities or industrial facility personnel necessary to receive clearance to drill at specified locations. The names of the personnel authorizing clearance will be documented in the field log book. The exact location of each boring shall also be reviewed by responsible plant personnel to ensure that the area is free of the facility-owned buried utilities.

Dig-safe must be contacted prior to drilling in public areas. Drilling locations shall be no closer than 25 ft to overhead utilities. The appropriate utility companies will be contacted to provide insulation of utility lines prior to commencement of drilling activities.

Personal Protective Equipment (PPE) and air monitoring equipment per the HASP will be provided and in use prior to the commencement of drilling.

The supervising geologist/engineer shall record the name of the drilling firm and the names of the driller and his assistant(s). The date, project location, project number, and weather conditions shall be recorded as well.

An accurate time log of drilling activities shall be kept. This log shall be kept in the field log book and shall include at a minimum, the following:

- time driller and rig arrive on site;
- time drilling begins;
- any delays in the drilling activities and the cause of such delays;
- time drillers go off site; and

- down time (those periods when drilling activities cease due to equipment malfunctions, weather, and ordered stoppages).

In addition, soil or rock boring logs, as appropriate (included in SOP), will be used to document detailed drilling observations.

2.2 Test Boring Method

Test borings can be conducted by a variety of drilling methods. The more commonly employed test boring techniques may be classified into six groups, based on the method used in displacing or removing subsurface material during the advancement of the borehole. The six drilling techniques are: displacement boring, wash boring, percussion drilling, rotary drilling, auger boring, and continuous sampling. The quality of the information obtained from the various boring methods varies greatly with the character of the subsurface geologic conditions, and careful consideration should be given in selecting the desired method. It may be necessary to employ more than one boring method to advance a particular borehole. The drilling techniques used on any particular project will be selected by the project manager and/or project geologist. In general, the wash, rotary, and auger boring are most common and described below.

2.2.1 Wash Boring

This method involves advancing casing, as required, and washing-out the soil to the bottom of the casing with a chopping bit to the desired sampling depth. The casing can be advanced by either spinning or hammering (pounding) the casing with a 300-pound hammer. The borehole may be stabilized with the casing, water, or drilling mud, and open samplers, such as the split-or solid-spoon type are driven into the undisturbed soil at the bottom of the borehole.

This method is most commonly used in soils which do not contain large cobbles and boulders, or cemented horizons. The wash boring method involves the introduction of drilling water and/or drilling mud to the borehole. The use of these materials and this method should be avoided whenever possible in conducting environmental investigations. The introduction of drilling fluids can alter the chemical composition of the groundwater

adjacent to the borehole, and may have an adverse effect on groundwater quality analyses on groundwater samples from monitoring wells installed in the completed borehole.

If it is necessary to use this technique to advance a borehole, the field geologist should determine the source and quality of the drilling water to be used in the boring process. The field geologist should not authorize the use of on-site or nearby groundwater or surface water bodies as the source of the drilling water, unless the proposed source has been sampled and analyzed for the full suite of contaminants considered likely to be present in the groundwater beneath the site. In all cases where drilling water or drilling mud are used to advance a borehole, the field geologist should consider obtaining a sample of the drilling fluid for potential analysis, at the discretion of the project manager and quality assurance/quality control (QA/QC) officer.

2.2.2 Rotary Drilling

This method is a variation of the wash boring technique, utilizing a rotary drill bit, rather than a chopping bit. It is employed primarily in advancing and cleaning the borehole to the required sampling depth, and is used in conjunction with air, water, or mud to bring the cuttings to the ground surface. This is the method generally preferred for exploratory test borings in the geo-technical consulting industry. This method is commonly used in environmental investigations when test borings are expected to encounter dense tills and coarse granular deposits (such as gravels), or are expected to terminate at depths exceeding 30 ft below the ground surface.

The primary disadvantage of this technique for environmental investigations is the introduction of drilling water or drilling mud. The use of air rotary drilling rigs is usually not appropriate for environmental investigations unless filters are used because the cuttings brought to the ground surface are ejected into the air adjacent to the drilling rig. Airborne contaminated soil could pose a health risk to workers at the site and nearby residents.

2.2.3 Auger Borings

This method involves advancing helical solid-flight or hollow-stem augers, with large mobile equipment. This is a fast method for advancing the borehole, without the use of drilling fluid, and particularly effective for boring through partially saturated or unsaturated material above the groundwater table. Conventional sampling procedures are employed

(split-spoon sampler). Some disturbance of the natural soil is caused by the advancing augers. Auger borings are primarily used for environmental investigations because they are cost-effective and do not involve the introduction of drilling fluids and muds to the subsurface environment.

Auger borings are difficult to advance below the groundwater table in granular soils because the soils can liquefy and move up the auger stem and/or collapse against the auger flights and cause excessive friction. This condition is commonly referred to as “running sands” or “blowing sands” in the drilling industry. Running sands can be counteracted with limited success by maintaining a constant hydraulic head in hollow-stem augers during the sampling operations. However, the constant head technique is not very effective when drilling more than approximately ten ft below the water table in granular soils.

Augers are difficult, and sometimes impossible, to advance to depths of greater than thirty ft in dense tills or coarse granular deposits (such as gravel).

Solid stem augers are not recommended for environmental investigations because soil samples cannot be obtained from discrete depth intervals. Soil samples from solid stem auger borings are typically collected from the surface of the auger flights as the cuttings are brought to the ground surface.

Slotted, hollow-stem augers are commonly used in environmental investigations when vertical profiling of a water-bearing unit is desired. The slotted lead auger is advanced to a pre-determined depth below the groundwater table, and water within the auger is purged with a pump to draw “undisturbed” formation water into the auger. A sample of the groundwater is obtained for analysis and the auger is advanced to the next groundwater-sampling interval.

2.3 Borehole Stabilization

2.3.1 Casing

Driving steel pipe or casing provided the most reliable and practical method of advancing a borehole to the required depth. Table 1 summarizes the numerous sizes and types of casing

available. The borehole is advanced by constant blows of a drive hammer (typically 300 pounds, falling over a distance of 24 inches) upon a drive head, which is attached to the casing. As the blows to drive the casing are constant, supplementary information may be obtained in the soil resistance by counting the casing blows and the resulting penetration. Casing blows are typically recorded for each ft of penetration of the casing. The casing can also be spun and pushed to the desired depth.

The casing is driven/spun in five-ft increments, with representative soil samples being obtained on a continuous basis or at the completion of each five-ft drive (depending upon the project specifications). After the casing is seated at the required depth, the borehole must be cleaned-out prior to obtaining a soil sample. In soft or loose soils, stability of the borehole is increased by keeping the casing filled with water or drilling fluids.

2.3.2 Drilling Mud

Drilling mud is a fluid employed to stabilize an encased borehole, or to improve sample quality and minimize soil disturbance in cased holes. Drilling mud may be prepared from commercially available products. Employing mud in a boring makes identification of the cuttings more difficult and hinders groundwater level observations.

The use of drilling mud is typically avoided when conducting environmental investigations. The use of drilling mud can reduce the permeability of the walls of the borehole, and therefore, lead to erroneous water level measurements. Additionally, the use of drilling mud introduces foreign material to the subsurface environment, which is not completely removed upon completion of the boring. The results of chemical analyses conducted on soil samples from boreholes advanced with drilling mud may not be representative of the natural (undisturbed) formation. Water samples obtained from wells installed in these boreholes may contain contaminants or parameters, which were not originally present in the groundwater prior to the use of the drilling mud.

Under no circumstances, should drilling mud be prepared with local or on-site clays. If the use of drilling mud is required to advance the boring, the mud should be prepared with commercially available clays, and samples of the mud mixture should be collected for potential analysis, if needed.

The basic mud mixture employed in the drilling industry is bentonite and fresh water (approximately 6 percent bentonite by weight: 50 pounds of bentonite per 100 gallons of water). Attapulgite clay is commonly used and will mix with salt water to prevent flocculation. Weight additives such as pulverized barite, hematite, galena, or other heavy minerals may be added to the mixture to increase the specific gravity in troublesome soils or under artesian conditions. The precise ingredients and their proportions in the mixture must be recorded for future reference, particularly when groundwater from wells installed in their borings is to be tested for dissolved metals and pH. Attention must be given to the particular group of contaminants exceed to be present in the groundwater beneath the site.

2.3.3 Hollow-Stem Augers

Hollow-stem augers are advanced hydraulically into the overburden to the required sampling depth. The auger acts as a casing during the advancement of the borehole. A removable center plug allows passage of the sampling equipment (typically a split-spoon sampler or Shelby tube) to the required depth. Augers are usually in five-ft sections. Some disturbances of the sampling zone may be created during the augering operation.

Drillers commonly dislike using the center plug and often attempt to complete the boring without using one. However, the center plug should always be used to prevent soil from entering the auger. If a center plug is not used, the split-spoon sampler may not be located at the desired sampling depth due to the presence of soil inside the auger.

2.4 **Borehole Cleaning**

Thorough and careful cleaning of the borehole is mandatory for obtaining representative, undisturbed samples. Careful measurement of tool length is required. The washing operation should not usually extend below the bottom of the casing (cohesive soils would be an exception). Special bits that deflect the wash water outward or upward should be employed, and only enough wash water should be pumped down the hole to bring the cuttings to the surface. Special shielded auger cleanouts should be employed in cohesive soils prior to obtaining undisturbed piston samples.

Where details of subsurface conditions are necessary, soil sampling shall be conducted using a split-spoon penetration sampler, driven with a 140-pound hammer with a free-fall

of 30 inches. This is a standard method of soil sampling as described in ASTM Designation D 1586. If necessary, the length of the hammer shaft will be measured and marked, to ensure a minimum drop of 30 inches. This technique should be conducted as follows:

1. The split-spoon sampler (spoon) consists of a 2-inch (outside diameter) by 1-3/8 inch (inside diameter), 18-inch to 24-inch length, heat-treated, case-hardened steel head, split-spoon, and shoe assembly. Split-spoon or split-tube samplers are the most generally accepted method for obtaining representative soil samples; however, from a geotechnical perspective, the samples obtained using a split-spoon are disturbed and unsatisfactory for some analyses. The head is vented to prevent pressure buildup during sampling and must be kept clean. A steel ball check valve is located in the head to prevent downward water pressure from acting on the sample. Removal of the check frequently causes sample loss.
2. The drive rods, which connect the spoon to the drive head, should have stiffness equal to or greater than that of the A-rod. In order to maintain only minimal rod deflection, on exceptionally deep holes, it may be preferable to use N-rods. The size of the drive rods must be kept constant throughout a specific exploration program, as the energy absorbed by the rods will vary with the size and weight of the rod employed. This is most important in geotechnical investigation
3. The drive head consists of a guide rod to give the drop hammer (140 pounds) free fall in order to strike the anvil attached to the lower end of the assembly. The guide rod must be at least 3.5 ft in length to insure the correct hammer drop.
4. The drop hammer used in determining standard penetration test (SPT) resistance must weigh 140 pounds and have a 2.5-inch diameter hole through the center, for passage of the drive head guide rod.
5. The hammer is raised with a rope activated by the drill rig cathead; no more than two turns of the rope should be allowed on the cathead. A 30-inch hammer drop is mandatory for proper SPT determination. Extreme care must be exercised to produce consistent results. Automatic trip hammers are commercially available which insure the 30 inch free-fall drop. When presentation of the soil structure is

critical (such as in liquefaction studies), the automatic trip hammer should be employed.

6. Attach the split-spoon sampler to the drill rods and lower the assembly to the bottom of the borehole. Measure the drill rod stickup to determine if heave or blow-up of the stratum has occurred. Note any penetration of the sampler into the stratum under the weight of the rods. The 140-pound hammer is raised 30 inches above the drivehead anvil and then allowed to free fall and strike the anvil. This procedure is repeated until the sampler has penetrated the full length of the sampler (18 to 24 inches depending on the sampler) into the stratum at the bottom of the borehole.
7. The number of blows of the hammer required for each 6 inch penetration is counted and recorded on the test boring log. A penetration rate of 100 blows per ft is normally considered refusal; however, this criterion may be varied depending upon the desired information. The penetration resistance (N) is determined by adding the second and third 6-inch resistance blow counts together. When other sizes and types of sampling and drive equipment are employed, ASTM reference tables may be used in converting the obtained blow count to the accepted SPT value.
8. The sampler is then withdrawn from the borehole, preferably by pulling on the rope. If the sampler is difficult to remove from the stratum, it may be necessary to remove it by hitting the drive head upward with short, light hammer strokes. Remove the sampler from the bottom of the borehole slowly to minimize disturbance. Keep the casing full of water during the removal operation.
9. Careful measurement of all drilling tools, samplers, and casing must be exercised during all phases of the test boring operations, to insure maximum quality and recovery of the sample.
10. The split-spoon is opened and carefully examined, noting all soil characteristics, color seam, disturbance, etc. A representative sample is selected and preserved in a screw-top, glass jar and properly labeled. In the event that more than one soil type is encountered in the split-spoon, each soil type should be preserved in a separate jar.

11. The supervising geologist/engineer shall record, at a minimum, the weight of the hammer, the length of the split spoon sampler, and the number of hammer blows on the spoon per 6 inches of penetration. Upon removal of the sampler, the earth materials shall be logged in accordance with SOP No. 210, Soil Sample Classification. When the number of blow counts exceeds 50 per 6 inches, the split spoon sampling shall be terminated and the number of blow per tenths of ft (for the last one-half ft) shall be recorded and noted as sampler refusal.
12. If a sample is to be retained, a pre-cleaned stainless steel or teflon coated spoon will be used to take the soil sample and fill the sample containers.
13. After the samples have been collected and if a well is not being installed in the boring, the borehole should backfilled with cement/bentonite or cement, the approximate location of the boring will be marked with an oak stake colored with highly visible spray paint. The boring number will also be written on the stake to identify the sample location for surveying purposes.

2.5 Logging Bedrock Cores

Rock coring is a method to obtain bedrock samples for geologic classification, facilitate their performance of permeability tests, and install groundwater monitoring wells within bedrock formations.

The supervising geologist/engineer on a drilling program is responsible for logging and recording geologic and geotechnical information from rock cores.

There is no universal core barrel or drilling equipment for rock coring. The geologic and topographic conditions, in addition to the requirements of the project will dictate the type of equipment to be employed on any specific project. The following factors lead to good production:

1. Insure a level and stable drilling platform before commencing boring.
2. Insure that the drill stem remains as nearly vertical as possible. On deep core holes, true alignment of the casing is critical. The driller may elect to use a

heavy drilling mud instead of casing to support the borehole walls; this procedure is not acceptable for environmental investigations.

3. Upon encountering boring refusal at the soil/bedrock interface, the casing should be firmly seated on the rock and thoroughly washed out before inserting the *diamond-bit core barrel*.
4. Inspect the selected core barrel and bit for wear, general cleanliness, and free movement of all parts. Reject any core barrel or bit that appears unsatisfactory. Upon selecting a satisfactory core barrel and bit, mount the core barrel and bit assembly on the drilling rods and lower it into the borehole until the bit touches the bedrock surface.
5. Pump drill fluid down the drill rods and observe a return flow before commencing drilling operations.
6. Carefully measure all length of rods, core barrel, and stick-up through all phases of the drilling to insure accurate depth determination.
7. The diamond-bit core barrel should be started in the hole and the rock drilled in continuous five-ft length intervals (runs) until the required depth is reached.
8. Drill with minimal vertical pressure and rotation. Most rigs are equipped with a selection of gear ratios and a variable hydraulically-controlled feed mechanism. Driller expertise in selecting the correct combination of speed and feed rate is invaluable.
9. Water return should be no more than what is just sufficient to bring the borehole cuttings to the surface.
10. Record the drilling time per ft, type of bit, estimate of bit wear, drill rig rpm, and feed pressure.
11. Upon completing each 5 ft core run, the core barrel is spun and lifted to break the core at the bottom of the run. After the core is broken off it should be withdrawn, labeled, and stored in an approved core box. Cores should be carefully handled to ensure their proper identification and placement in correct order. Care should be taken to recover as large a percentage of unbroken core as possible.

12. Carefully place the rock core in the core box with wooden partitions so that the cores from each boring will be kept separate. The core should always be placed in the core box in book fashion with the top of the run at the upper left corner and the remaining core placed sequentially from left to right and from the top left corner to the lower right corner. Place a wooden partition at the beginning and end of each core run. The core should fit snugly in the box so that it will not roll or slide and suffer additional breakage. The wooden blocks should be labeled with the Run Number and depths of the beginning and end of each run.

Each core box should only contain cores from a single boring. Never place the core from more than one test boring in a core box. In addition, wherever core is lost due to the presence of a cavity or large discontinuity (open or filled), a spacer should be placed in the proper position in the core box. The spacer should be labeled with the depth range and thickness of the missing core, and the reason for the missing core (e.g., cavity, large joint, etc.).
13. Carefully examine and classify the rock, and measure the recovery and RQD in percent. Record all information on the core boring report.
14. If 100% recovery was not obtained, sound the borehole to determine if the missing core still remains in the bottom of the borehole.
15. Always terminate each boring with 100% recovery, in order to insure that appropriate knowledge is available of their materials.
16. The core box should be marked on the top and two ends with the client's name, site identification, boring number, depth range, and box number.
17. The core barrel and drilling tools must be steam-cleaned or washed upon completion of the borehole to preclude cross contamination between successive boreholes.
18. Wash water used during the core drilling should not be re-circulated to the borehole, if possible.

2.5.1 Wireline Drilling

The procedures for wireline drilling are also the same as for conventional rock coring, with the exception that the core barrel is designed so that the inner core barrel can be raised in a

wireline without removing the entire drill string, outer core barrel, and bit. The drilling rig must be equipped with a wireline hoist.

2.5.2 Oriented Core

If precise spatial orientation of rock bedding, foliation, and discontinuities are required, it is recommended that the Christensen Diamond Products Series D-3, NWD-3 core barrel, or equivalent, be employed.

2.5.3 Shotcore Drilling

Shotcore drilling is usually employed to produce large-diameter rock core (2 to 6 ft and larger). The core is cut by the abrasive action of chilled steel shot fed to a rotating steel bit. Shotcore procedures are as follows:

1. Lower the assembled shotcore barrel to the bedrock surface.
2. Drop one or two handfuls of chilled shot down the center rod. Connect the bit to the drilling spindle and slowly turn by hand with a pipe wrench. A gritty feeling indicates that the shot is beneath the bit.
3. Lift the bit off the bottom and introduce the fresh water supply. When water return appears at the surface, lower the bit to the bedrock surface.
4. Drill feed must be manual with only enough downward pressure to follow the bit. This is an abrasive action and too much shot will wear the core barrel and too little will not core the rock. Driller expertise and careful attention are absolutely critical in successful shotcore drilling.
5. Regulate water flow so that it just allows the cuttings and slivers of steel to be carried over the top of the casing. Add additional shot as required.
6. A good flow of muddy slurry to the surface indicates that the rock is being drilled.
7. If water return is clear, but contains fine particles of steel, this is an indication that an excess of shot has been used. Flush the hole and start again.
8. Record the drilling rate and reface the bit shoe after every withdrawal by squaring up the face with a hammer.

9. To recover the core, a hard, uniformly-graded pea gravel is fed into the center rod as it is slowly rotated so the gravel is grouted between the core and the core barrel, and the entire unit is pulled to the surface. On occasion, it may be necessary to remove the core barrel and drill a small diameter hole in the center of the core while it is still in the hole, and then drive a casing retriever into the core before retrieval is possible.

2.5.4 Preservation of Rockcore

The following information shall be included in a rock core run log:

- The depth and length of the core run.
- The coring rate, down pressure, and torque and rotation speed. This information can be obtained from the driller.
- The color of the core wash water. Any changes, loss of return water, or gain of return water will be noted.
- The recovery of the core run recorded as length of rock recovered over the length of the core run.
- The Rock Quality Designation (RQD) of the run. RQD is reported as the sum of inches of all naturally fractured rock core pieces larger than four inches over the total number of inches in the run. The length of the piece will be determined by the distance between naturally occurring fractures.
- The rock type(s) and their location in the core run, rotating color, mineralogy, texture, fossil content, effervescence in hydrochloric acid (HCL), and any other data of geologic significance.
- Any structure in the core, including fractures, clay seams, vugs, bedding, fissility, and any other data of geologic or geotechnical significance.

Rock cores shall be stored in a core box in the exact sequence in which they were removed from the ground. Core runs will be separated by wooden blocks clearly marked with the depth of the run. The top of the core box shall be marked with the project name, location, project number, boring number, and the depths of the core runs in that box. The front and

one end of the core box shall be marked with project name, boring number, and depths of the core runs in that box. All core pieces shall be oriented in the box as they fit together. A black and white stripe shall be drawn down the length of the core, so that core orientation can easily be determined.

2.6 Photographing Soil and Rock Samples from Borings

If soil samples are to be documented with photographs, the photographs should be taken while the soil samples are still in the split spoon. If smearing of the sample has occurred, a fresh exposure can be made by scraping with a pen knife or other similar object. The spoon and sample should be placed in a good light, preferably against a solid colored background. A ruler for scale and a tag identifying the sample should be placed in the picture. The identifier tag must have the sample number, depth and project name or number written so as to be legible in the photograph. Any photographs taken should be recorded in the field log book.

Rock core samples are photographed in the wooden core box. The rock should be wetted to enhance the color and textural changes in the rock. Due to the relatively large size of most core boxes, the photographer (when possible) should stand up on a chair, tail gate, car bumper or other perch in order to photograph the box from directly above, and get the entire box in the camera's field of view. The photograph should include a ruler for scale and an identifier tag indicating the project name and number, the boring number, the date, and the depths of the various core runs.

STANDARD OPERATING PROCEDURE NO. 240

DIRECT PUSH SOIL SAMPLING

Prepared by: D.G.L. Date: 9 February 2007

Reviewed by: Peter J. deKor Date: 12 February 2007

Approved by: Mandha Date: 13 February 2007

SOP No. 240

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
2. EQUIPMENT	2
3. PROCEDURES	2

**STANDARD OPERATING PROCEDURE NO. 240
DIRECT PUSH SOIL SAMPLING**

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for conducting direct push technology (DPT) soil sampling activities.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of DPT soil sampling is to collect subsurface soil samples at depth-discrete intervals.

2. EQUIPMENT

A DPT rig will be used to conduct subsurface soil sampling activities. The DPT (Geoprobe®, PowerProbe™ or similar) device may be operated using a dual tube methodology which allows the collection of subsurface soil samples through an outer casing that is set to maintain the integrity of the boring. Using the DPT rig, borings are advanced by simultaneously driving an outer stainless steel casing and disposable inner Lexan® tube into the ground. Upon reaching the desired penetration depth, the inner Lexan® tube is extracted to collect the discrete subsurface soil samples, leaving the outer casing in place. To sample the next interval of soil, a new length of Lexan® tubing is then inserted into the outer casing (already in the ground) attached to a length of drive pipe, and another length of outer casing is attached to the top of the outer casing that is already in the ground. The following materials should be available, as required, during the subsurface soil sampling:

- equipment necessary for surface soil sampling (see SOP 200);
- Personal Protective Equipment (PPE) and air monitoring equipment as required by the HASP;
- DPT sampling equipment;
- decontamination equipment per the QAPP and FSP;
- measuring device;
- photoionization detector (PID);
- camera; and
- field log book and forms as specified in other SOPs.

3. PROCEDURES

The following procedures will be employed to collect subsurface soil samples:

1. Ensure that all drilling sites are safe by carrying out appropriate subsurface utility clearance.
2. Don the appropriate PPE and begin air monitoring as specified in the HASP.
3. Set-up an equipment cleaning station, and decontaminate reusable equipment as described in the FSP. Use new, clean, disposable materials when decontamination is not appropriate (e.g., disposable gloves, sampling tubes, and dedicated drive points).
4. Assemble the dual probe (outer steel casing and inner Lexan® tube) sampling apparatus or other DPT tool.
5. Drive the sampling tools to the appropriate sampling zone.
6. When the desired depth for the collection of a subsurface soil sample is reached, retrieve the inner Lexan® tube and segregate the soil sample, as needed. If an alternative DPT tool is used, push to the appropriate depth and sample following the equipment operations instructions.
7. Note the soil type, color, odor, amount of recovery, and screen the soil core for volatile organic compound (VOC) analysis using the photo-ionization detector (PID). All field data shall be recorded in the soil sample sheet (see SOP No. 200.) Sample soils for laboratory analysis per requirements of the FSP and instruction in the SOP No. 200 for Soil Sampling. In some cases, depending upon FSP requirements, PID field screening will be used to select intervals for sampling.
8. Decontaminate non-disposable equipment or tools that may have come into contact with subsurface soil (refer to FSP or QAPP.)
9. Discard all disposable equipment used during sampling activities in a designated location.
10. Abandon the borehole with bentonite pellets; hydration is not necessary.
11. If the DPT is used for drilling more than 4 ft, documentation will switch to a drilling log (see SOP No. 230 for rock and soil borings).

STANDARD OPERATING PROCEDURE NO. 300

SURFACE WATER AND SEDIMENT SAMPLING

Prepared by: D.G.L. Date: 9 February 2007

Reviewed by: Pete J. deHaan Date: 12 February 2007

Approved by: Nandha Date: 13 February 2007

SOP No. 300

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	2
2. PROCEDURES	3
2.1 Order of Samples	3
2.2 Surface Water Sampling Procedure.....	3
2.3 Sediment Sampling Procedure.....	5

STANDARD OPERATING PROCEDURE NO. 300 SURFACE WATER AND SEDIMENT SAMPLING

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the logistics, collection techniques, and documentation requirements for collecting surface water and sediment samples. The surface water and sediment sampling record to be used during sampling activities is provided with this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of surface water and sediment sampling is to obtain a representative sample of these media for laboratory analysis of contaminants of concern at a given site. This objective requires that the sample be both free of unsuitable material and be of sufficient quantity and quality for analysis by the selected analytical method.

1.3 Equipment

The following equipment is needed for surface water sampling:

- boots, waders, and Personal Protective Equipment (PPE) as required by HASP;
- sample containers per the FSP;
- indelible markers;
- wooden stakes and highly visible spray paint;
- decontaminated Pyrex® measuring cup;
- waterproof field log book and sample log form (included in SOP) per the FSP;
- boat, if appropriate;
- YSI or equivalent multi-parameter water meter (temperature, pH, conductivity, dissolved oxygen (DO), ORP); and
- turbidity meter.

The following equipment is needed for sediment sampling:

- boots, waders, and PPE as required by the HASP;
- decontaminated stainless steel spoons, hand auger, or ponar dredge (for river/stream sediments);
- indelible markers;
- digital scale (accurate to +/- 0.1 grams);
- disposable sampling syringe;
- stainless-steel mixing bowl;
- sample containers per the FSP;
- wooden stakes and highly visible spray paint; and
- waterproof field log book and sample log form (included in SOP) per the FSP.

2. PROCEDURES

2.1 Order of Samples

If both stream sediment and water samples are to be collected concurrently, the water samples should be taken first in order to avoid introducing sediment into the water column from sediment collection activities.

In flowing streams or runoff channels, samples should be collected first from the furthest point downstream. The remaining samples will be taken while proceeding upstream.

2.2 Surface Water Sampling Procedure

The person collecting the samples in most cases will have to enter the water body. For flowing streams this will necessitate the donning of PPE (i.e., boots or waders, and latex inner gloves and chemical-resistant outer gloves). All samples in flowing water bodies will be taken facing upstream. Samples taken from standing puddles, pools, and drainage ditches should be taken without disturbing the sediments. This may be accomplished by the use of a remote sampler (e.g., a sample bottle held on a long pole with a gimballed yoke).

Surface water sampling will entail field parameter measurement. A YSI or equivalent multiparameter meter capable of measuring pH, ORP, temperature, conductivity, and DO will be calibrated at the beginning of each sampling day according to the manufacturer's instructions. A separate turbidity meter will be used.

Note that some bottleware comes pre-preserved, with pH targets listed in the FSP and QAPP. For at least one container for each analysis, it is necessary to confirm with pH paper that pH targets are met after filling.

The sampling procedure for surface water is listed below.

1. Prior to collecting any water samples, place a completed waterproof sample label/tag on each container. Complete the label/tag according to the QAPP. Fill

in the information with a waterproof ink pen before sample collection. This will prevent difficulty in filling out a wet label/tag.

2. Face upstream. Wearing gloves, submerge measuring cup, without disturbing any sediment.
3. Slowly fill the volatile organic compound (VOC) vials first. Fill the first pre-preserved vial to slightly below the rim by pouring from the measuring cup. Slightly overfill the vial, creating a positive meniscus. Invert the cap and moisten it with sample water, and carefully place and screw on the cap. Turn the vial upside down and tap lightly to check for air bubbles. Air bubbles of any size should not be present, since they can introduce significant error in the analysis of the sample. If any air bubbles are present, remove the cap and add drops of sample water to create a meniscus, and cap again, checking again for air bubbles. Repeat the process until the vial is capped and free of bubbles. Repeat process for the other two vials.
4. Using the same measuring cup to sample water, continue to fill the remaining pre-preserved sample bottles. Where samples are to be submitted for dissolved metals, and field filtration is required, 500 mL of water collected from the sampling point will be filtered in the field using a portable pump and sterile, dedicated filtration devices. The filtered sample will be preserved subsequent to the filtration.
5. The temperature, pH, DO, ORP, turbidity, and conductivity of the sampled water should be determined immediately after sample collection. Where possible, field measurements of these parameters will be measured *in situ*, rather than from a sample container. Measurements will be taken by direct placement of the probe in the water body. These measurements will not be taken from any sample bottles being sent to the analytical laboratory for chemical analysis.
6. All samples will be immediately placed on ice (preferably double-bagged ice packs) to remain at 4°C ($\pm 2^\circ\text{C}$) prior to and during shipment to the laboratory. The sample containers will be stored in a cooler until further processing. Refer to SOP No. 410 for sample shipping.
7. Detail in the field log book the sample location, identification, and time. Complete the sample log sheet with the following:

- sample identification;
 - location of the sample (sketch of the sample point);
 - time and date sample was taken;
 - personnel performing the task;
 - description of the sample (color, odor, turbidity, etc.);
 - runoff conditions; and
 - other pertinent observations.
8. Place a spray-painted wooden stake at the edge of the stream or near the sample point with the location identification number on it. The stake will be located by survey or global positioning system (GPS) unit for inclusion on a site map.

2.3 Sediment Sampling Procedure

The following procedure will be followed for sediment sampling.

1. Don PPE as described in Section 2.2.
2. Select a sample location that is representative of sediment depositional areas. This might mean a sandbar in the middle of a stream, the inside corner of a stream bed in a meander, or a deep pool where water velocities are reduced.
3. Use a pre-cleaned, dedicated stainless steel spoon (that will fit inside the sample jar), to collect the sample except for samples for VOC analysis, which will be collected using an open barrel, disposable syringe.
4. All samples should be taken within the top 6 inches of the stream bed. Remove any vegetation debris (leaves, roots, bark) along with any large stones from the sample so that only the finer soil material is collected. Samples should be obtained using the appropriate sampling device.
5. Excess liquids collected along with the sediment sample will be allowed to decant from the sampler prior to sample containerization.
6. Sediment samples for VOC analysis shall be collected directly from the dredge/auger sampling device using an open barrel, disposable syringe.

7. The syringe will be filled with undisturbed soil of the following volumes: 5 grams of soil for low-level analysis (added to the 5 mL of sodium bisulfate); and/or 15 grams of soil for high level analysis (added to the 15 mL of methanol).
8. For high level VOC analysis, the soil will be extruded from the syringe into a preserved VOC vial, containing “purge and trap” grade methanol (15 mL).
9. For low level VOC analysis, the soil will be extruded from the syringe into a preserved VOC vial, containing sodium bisulfate (5 mL), a stir bar, and distilled water.
10. Any particles or grains present on the container rim or cap will be removed to ensure an adequate vial seal. The VOC vial will be capped quickly and labeled/tagged with sample identification, date, and time of collection. The container/preservative/sample will then be weighed, and the post-collection weight will also be recorded on the chain of custody. The objective sample weights (5 grams for low-level analysis, and 15 grams for high level analysis) will be achieved (+/- 10%) with the use of the digital scale. Should insufficient sample volume be added to the preserved container, a stainless-steel spatula will be used to add a small portion of sample until the target weight is achieved (or exceeded within 10%).
11. In the event that a field screening technique (instrument reading, visual staining of the soil, or olfactory observation) indicates the presence of VOCs or hydrocarbons, note the observations or instrument readings in the field logs.
12. Once the VOC fraction has been acquired, obtain sample material for the other parameters to be analyzed.
13. Detail in the field log book the sample location, identification, and time. Complete the Sample Log Sheet (attached) with the following:
 - sample identification;
 - location of the sample;
 - time and date sample was taken;
 - personnel performing the task;
 - visual or sensory description of the sample;

- brief sediment description (color, texture, appearance);
 - runoff conditions; and
 - other pertinent observations.
14. Place a wooden stake at the edge of the stream or near the sample point with the sample identification number on it. This stake will be located by survey or GPS unit for inclusion on a site map.

STANDARD OPERATING PROCEDURE NO. 410

PACKAGING AND SHIPPING OF ENVIRONMENTAL SAMPLES

Prepared by: DG.L Date: 9 February 2007

Reviewed by: Pete J. deHaan Date: 12 February 2007

Approved by: Nandha D Date: 13 February 2007

SOP No. 410

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
1.3 Equipment.....	1
2. PROCEDURES	2

**STANDARD OPERATING PROCEDURE NO. 410
PACKAGING AND SHIPPING OF ENVIRONMENTAL SAMPLES**

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to establish packaging and shipping requirements and guidelines for environmental sample shipping. Proper packaging and shipping is necessary to ensure the protection of the integrity of environmental samples shipped for analysis.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The purpose of appropriate packaging and shipping for environmental samples is to protect the integrity of environmental samples shipped for analysis and to ensure that environmental samples arrive at the environmental laboratory in good condition for analysis.

1.3 Equipment

Equipment needed for packaging and shipping of environmental samples includes:

- coolers with return address of site office written on inside lid;
- heavy-duty plastic overbags, cooler-size;
- plastic zip-top bags, small and large;
- plastic packing tape;
- duct tape;
- bubble wrap;
- ice;
- chain-of-custody seals;
- completed Chain-of-Custody Record;
- completed bill of lading or airbill.

The term “Environmental Sample” refers to any sample that has less than reportable quantities of any hazardous constituents according to Department of Transportation (DOT) 49 CFR - Section 172.

2. PROCEDURES

The following steps must be followed when packing for shipment by air:

1. Select a sturdy cooler in good repair. Secure and tape the drain plug (inside and outside) with duct tape.
2. Be sure the caps on all bottles are tight (will not leak); check to see that labels/tags and Chain-of-Custody Records are completed properly.
3. Double-bag ice in large plastic zip-top bags and properly seal.
4. Place all bottles in separate and appropriately-sized plastic zip-top bags and close the bags. Up to three volatile organic compound (VOC) vials may be packed in one bubblewrap envelope placed inside a zip-top bag; alternatively, nine VOC vials may be packed in a foam cube with vial slots, with the cube packed in a zip-top bag. Glass bottles should be wrapped in bubble wrap before placing in zip-top bags.

5. Place two to four inches of packing peanuts or vermiculite into the bottom of the cooler. Alternatively, place two layers of large-bubble bubble wrap on the bottom of the cooler.
6. Place a clear, cooler-size overwrap bag in the cooler, place one layer of ice and a temperature blank in the bottom of the bag, and then place the bottles in the bag with sufficient space to allow for the addition of a second layer of ice bags over the sample containers. It is preferable to place glass sample bottles and jars into the cooler vertically. Due to the strength properties of a glass container, there is much less chance for breakage when the container is packed vertically rather than horizontally.
7. Place the second layer of ice bags on top of the samples. Close and securely fasten the top of the large overbag with tape (preferably duct tape).
8. Place the completed Chain-of-Custody Record for the laboratory into a plastic zip-top bag, tape the bag to the inner side of the cooler's lid, and then close the cooler.
9. Packing tape shall be wrapped around each end of the cooler two times, and completed Chain-of-Custody seals affixed to the top opposite sides of the cooler half on the tape so that the cooler cannot be opened without breaking the seal. Wrap clear tape over custody seals.
10. The shipping containers must be marked with THIS END UP, and arrow labels, which indicate the proper upward position of the container, should be affixed to the cooler. A label containing the name and address of the shipper shall be placed on the outside of the container. Labels used in the shipment of hazardous materials (such as Cargo Only Air Craft, Flammable Solids, etc.) are not permitted to be on the outside of the container used to transport environmental samples and shall not be used.

STANDARD OPERATING PROCEDURE NO. 500

AMBIENT AIR SAMPLING

Prepared by: Jill W. Johnson Date: 14 February 2007

Reviewed by: Pete J. deHaven Date: 14 February 2007

Approved by: Mandana Date: 14 February 2007

SOP No. 500

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview.....	1
1.2 Objective.....	1
Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, Compendium Method IO-2.1 Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM10 using High Volume (HV) Sampler, EPA/625/R-96/010a	

STANDARD OPERATING PROCEDURE NO. 500 AMBIENT AIR SAMPLING

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to direct field personnel in the methods for conducting ambient air sampling for inorganic compounds in ambient air. Geosyntec will follow the methods outlined in the “Compendium of Methods for the Determination of Inorganic Compounds in Ambient Air, Compendium Method IO-2.1 Sampling of Ambient Air for Total Suspended Particulate Matter (SPM) and PM10 using High Volume (HV) Sampler”, EPA/625/R-96/010a, June 1999, which is included as this SOP.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

The objective of ambient air sampling is to obtain information used to protect on-site workers from hazardous levels of inorganic compounds during site activities.

**Compendium of Methods
for the Determination of
Inorganic Compounds
in Ambient Air**

Compendium Method IO-2.1

**SAMPLING OF AMBIENT AIR
FOR TOTAL SUSPENDED
PARTICULATE MATTER (SPM)
AND PM₁₀ USING
HIGH VOLUME (HV) SAMPLER**

Center for Environmental Research Information
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, OH 45268

June 1999

Method IO-2.1

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This Method is the result of the efforts of many individuals. Gratitude goes to each person involved in the preparation and review of this methodology.

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DISCLAIMER

This Compendium has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Method IO-2.1
Sampling of Ambient Air for Total Suspended Particulate
Matter (SPM) and PM₁₀ Using High Volume (HV) Sampler

TABLE OF CONTENTS

	<u>Page</u>
1. Scope	2.1-1
2. Applicable Documents	2.1-3
2.1 ASTM Documents	2.1-3
2.2 Other Documents	2.1-3
3. Summary of Method	2.1-3
4. Significance	2.1-4
5. Definitions	2.1-4
6. Apparatus Description	2.1-7
6.1 General Description	2.1-7
6.2 Filter Medium	2.1-7
6.3 Flow Control System	2.1-8
7. Calibration	2.1-9
7.1 Introduction	2.1-9
7.2 Summary of Calibration Procedures	2.1-10
7.3 Certification of an Orifice Transfer Standard	2.1-10
7.4 Procedure for a Mass-Flow-Controlled (MFC) High Volume Sampler	2.1-13
7.5 Procedure for a Volumetric-Flow-Controlled (VFC) Sampler	2.1-20
7.6 Sampler Calibration Frequency	2.1-26
8. Filters	2.1-26
8.1 Pre-weighing of Filters	2.1-26
8.2 Filter Handling	2.1-27
8.3 Visual Filter Inspection	2.1-27
9. Sampling Procedure	2.1-28
9.1 Summary	2.1-28
9.2 Siting Requirements	2.1-29
9.3 Sampler Installation Procedures	2.1-29
9.4 Sampling Operations	2.1-30
9.5 Sample Validation and Documentation	2.1-37
10. Interferences	2.1-38
11. Calculations, Validations, and Reporting of TSP and PM ₁₀ Data	2.1-39
12. Records	2.1-44
12.1 MFC Sampler	2.1-44
12.2 VFC Sampler	2.1-44
13. Field QC Procedure	2.1-45
13.1 QC Flow-Check Procedure--MFC Sampler	2.1-46
13.2 QC Flow-Check Procedure--VFC Sampler	2.1-50
14. Maintenance	2.1-53
14.1 Maintenance Procedures	2.1-53
14.2 Recommended Maintenance Schedules	2.1-53
14.3 Refurbishment of HV Samplers	2.1-55
15. References	2.1-55

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Chapter IO-2 Integrated Sampling of Suspended Particulate Matter (SPM)

Method IO-2.1 SAMPLING OF AMBIENT AIR FOR TOTAL SUSPENDED PARTICULATE MATTER (SPM) AND PM₁₀ USING HIGH VOLUME (HV) SAMPLER

1. Scope

1.1 Suspended particulate matter (SPM) in air generally is a complex, multi-phase system of all airborne solid and low vapor pressure liquid particles having aerodynamic particle sizes from below 0.01-100 μm and larger. Historically, SPM measurement has concentrated on total suspended particulates (TSP), with no preference to size selection.

1.2 The U. S. Environmental Protection Agency (EPA) reference method for TSP is codified at 40 CFR 50, Appendix B. This method uses a high-volume sampler to collect particles with aerodynamic diameters of approximately 100 μm or less. The high-volume samples 40-60 ft^3/min of air with the sampling rate held constant over the sampling period. The high-volume design causes the TSP to be deposited uniformly across the surface of a filter located downstream of the sampler inlet. The TSP high-volume can be used to determine the average ambient TSP concentration over the sampling period, and the collected material subsequently can be analyzed to determine the identity and quantity of inorganic metals present in the TSP.

1.3 Research on the health effects of TSP in ambient air has focused increasingly on particles that can be inhaled into the respiratory system, i.e., particles of aerodynamic diameter less than 10 μm . The health community generally recognizes that these particles may cause significant adverse health effects. Recent studies involving particle transport and transformation strongly suggest that atmospheric particles commonly occur in two distinct modes: the fine (< 2.5 μm) mode and the coarse (2.5-10.0 μm) mode. The fine or accumulation mode (also termed the respirable particulate matter) is attributed to growth of particles from the gas phase and subsequent agglomeration, while the coarse mode is made of mechanically abraded or ground particles. Particles that have grown from the gas phase (either because of condensation, transformation, or combustion) occur initially as very fine nuclei-0.05 μm . These particles tend to grow rapidly to accumulation mode particles around 0.5 μm which are relatively stable in the air. Because of their initially gaseous origin, particle sizes in this range include inorganic ions such as sulfate, nitrate, ammonia, combustion-form carbon, organic aerosols, metals, and other combustion products. Coarse particles, on the other hand, are produced mainly by mechanical forces such as crushing and abrasion. Coarse particles, therefore, normally consist of finely divided minerals such as oxides of aluminum, silicon, iron, calcium, and potassium. Coarse particles of soil or dust mostly result from entrainment by the motion of air or from other mechanical action within their area. Since the size of these particles is normally > 2.5 μm , their retention time in the air parcel is shorter than the fine particle fraction.

1.4 On July 1, 1987, the U. S. Environmental Protection Agency (EPA) promulgated a new size-specific air quality standard for ambient particulate matter. This new primary standard applies only to particles with aerodynamic diameters \leq 10 micrometers (PM₁₀) and replaces the original standard for TSP. To measure concentrations of these particles, the EPA also promulgated a new federal reference method (FRM). This method is based on the separation and removal of non-PM₁₀ particles from an air sample, followed by filtration and gravimetric analysis of PM₁₀ mass on the filter substrate.

1.5 The new primary standard (adopted to protect human health) limits PM_{10} concentrations to $150 \mu\text{g}/\text{std. m}^3$ averaged over a 24-h period. These smaller particles are able to reach the lower regions of the human respiratory tract and, therefore, are responsible for most of the adverse health effects associated with suspended particulate pollution. The secondary standard, used to assess the impact of pollution on public welfare, has also been established at $150 \mu\text{g}/\text{std. m}^3$.

1.6 Ambient air SPM measurements are used (among other purposes) to determine whether defined geographical areas are in attainment or non-attainment with the national ambient air quality standards (NAAQS) for PM_{10} . These measurements are obtained by the States in their State and local air monitoring station (SLAMS) networks as required under 40 CFR Part 58. Further, Appendix C of Part 58 requires that the ambient air monitoring methods used in these EPA-required SLAMS networks must be methods that have been designated by the EPA as either reference or equivalent methods.

1.7 Monitoring methods for particulate matter are designated by the EPA as reference or equivalent methods under the provisions of 40 CFR Part 53, which was amended in 1987 to add specific requirements for PM_{10} methods. Part 53 sets forth functional specifications and other requirements that reference and equivalent methods for each criteria pollutant must meet and explicit test procedures by which candidate methods or samplers are to be tested against those specifications. General requirements and provisions for reference and equivalent methods are also given in Part 53, as are the requirements for submitting an application to the EPA for a reference or equivalent method determination.

1.8 Several methods are available for measuring SPM in ambient air. As mentioned earlier, the most commonly used device is the high-volume sampler, which consists essentially of a blower and a filter, and which is usually operated in a standard shelter to collect a 24-h sample. The sample is weighed to determine concentration and may be analyzed chemically. The high volume sampler is considered a reliable instrument for measuring the mass concentration of TSP in ambient air. When EPA first regulated TSP, the NAAQS was stated in terms of SPM captured on a filter with aerodynamic particle size of $< 100 \mu\text{m}$ as defined by the TSP sampler; therefore, the TSP sampler was used as the reference method.

1.9 Under Part 53 requirements, reference methods for PM_{10} must be shown to use the measurement principle and meet other specifications set forth in 40 CFR 50, Appendix J. They must also include a PM_{10} sampler that meets the requirements specified in Subpart D of 40 CFR 53. Appendix J specifies a measurement principle based on extracting an air sample from the atmosphere with a powered sampler that incorporates the inertial separation of PM_{10} size range particles followed by the collection of PM_{10} particles on a filter over a 24 h period. The average PM_{10} concentration for the sample period is determined by dividing the net weight gain of the filter over the sample period by the total volume of air sampled, corrected to EPA's standard temperature (25°C) and standard pressure (760 mm Hg). Other specifications for flow rate control and measurement, flow rate measurement device calibration, filter media characteristics and performance, filter conditioning before and after sampling, filter weighing, sampler operation, and correction of sample volume to EPA reference temperature and pressure are prescribed in Appendix J. In addition, sampler performance requirements in Subpart D of Part 53 include sampling effectiveness (the accuracy of the PM_{10} particle size separation capability) at each of the three wind speeds and at "50% cutpoint" (the primary measure of $10\text{-}\mu\text{m}$ particle size separation). Field tests for sampling precision and flow rate stability are also specified. In spite of the instrumental nature of the sampler, this method is basically a manual procedure, and all designated reference methods for PM_{10} are therefore defined as manual methods.

1.10 This document describes the procedures for sampling SPM in ambient air for both TSP and PM₁₀ based upon active sampling using a high volume air sampler. The ambient particles are collected on quartz fiber filters. The sampler collects TSP or PM₁₀ ambient particles depending upon the type of inlet selected.

2. Applicable Documents

2.1 ASTM Documents

- D4096 *Application of the High Volume Sample Method for Collection and Mass Determination of Airborne Particulate Matter.*
- D1356 *Definition of Terms Related to Atmospheric Sampling and Analysis.*
- D1357 *Practice for Planning the Sampling of the Ambient Atmosphere.*
- D2986 *Method for Evaluation of Air Assay Media by the Monodisperse DOP (Diethyl Phthalate) Smoke Test.*

2.2 Other Documents

- U. S. Environmental Protection Agency, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume I: A Field Guide for Environmental Quality Assurance*, EPA/600/R-94/038a.
- U. S. Environmental Protection Agency, *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II: Ambient Air Specific Methods (Interim Edition)*, EPA/600/R-94/038b.
- *Reference Method for the Determination of Particulate Matter in the Atmosphere*, 40 CFR 50, Appendix J.
- *Reference Method for the Determination of Suspended Particulates in the Atmosphere (High Volume Method)*, 40 CFR 50, Appendix B.
- *Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air*, 40 CFR 50, Appendix G.
- *Reference Method for the Determination of Suspended Particulates in the Atmosphere (PM₁₀ Method)*, 40 CFR 50, Appendix J.

3. Summary of Method

3.1 The sampling of a large volume of atmosphere, 1,600-2,400 m³ (57,000-86,000 ft³), with a high-volume blower, typically at a rate of 1.13-1.70 m³/min (40-60 ft³/min), is described in this method. The calibration and operation of typical equipment used in this sampling is also described.

3.2 Air is drawn into the sampler and through a glass fiber or quartz filter by means of a blower, so that particulate material collects on the filter surface. Without a 10 µm size-selective inlet, particles of 100 µm size and less enter the sampling inlet and are collected on the downstream filter. The collection efficiencies for particles larger than 20 µm decreases with increasing particle size, and it varies widely with the angle of the wind with respect to the roof ridge of the sampler shelter. When glass fiber filters are used, particles 100-0.1 µm or less in diameters are ordinarily collected. With a size-select inlet, particles 10 µm diameter or less are collected on the quartz filter.

3.3 The upper limit of mass loading is determined by plugging the filter medium with sample material, which causes a significant decrease in flow rate. For very dusty atmospheres, shorter sampling periods will be necessary.

3.4 The volume of air sampled is determined by a flow-rate indicator. The instrument flow-rate indicator is calibrated against a reference orifice meter. The latter is a working standard which, in turn, has been calibrated against a master flow meter certified by the National Institute of Standards and Technology (NIST).

3.5 Airborne particulate matter retained on the filter may be examined or analyzed chemically by a variety of methods (ICP, ICP/MS, AA, GFAA, and NAA) as delineated in Inorganic Compendium Methods IO-3.2 through IO-3.7.

4. Significance

4.1 The area of toxic air pollutants has been the subject of interest and concern for many years. Recently the use of receptor models has resolved the elemental composition of atmospheric aerosol into components related to emission sources. The assessment of human health impacts resulting in major decisions on control actions by federal, state and local governments is based on these data. Accurate measures of toxic air pollutants at trace levels is essential to proper assessments.

4.2 The high volume sampler is commonly used to collect the airborne particulate component of the atmosphere. A variety of options available for the sampler provides broad versatility and allows the user to develop information about the size and quantity of airborne particulate material and, using subsequent chemical analytical techniques, information about the chemical properties of the particulate matter. The advent of inductively coupled plasma spectroscopy has improved the speed and performance of metals analysis in many applications.

5. Definitions

[Note: Definitions used in this document are consistent with those used in ASTM Methods. All pertinent abbreviations and symbols are defined within this document at point of use.]

5.1 High-Volume Air Sampler (HV). A device for sampling large volumes of an atmosphere for collecting the contained particulate matter by filtration. Consists of a high-capacity blower, a filter to collect suspended particles, and a means for measuring the flow rate.

5.2 Working Flow-Rate Standard. A flow-rate measuring device, such as a standard orifice meter, that has been calibrated against a master flow-rate standard. The working flow-rate standard is used to calibrate a flow measuring or flow rate indicating instrument.

5.3 Master Flow-Rate Standard. A flow-rate measuring device, such as a standard orifice meter, that has been calibrated against a primary standard.

5.4 Primary Flow-Rate Standard. A device or means of measuring flow rate based on direct primary observations such as time and physical dimensions.

5.5 Spirometer. A displacement gasometer consisting of an inverted bell resting upon or sealed by liquid (or other means) and capable of showing the amount of gas added to or withdrawn from the bell by the displacement (rise or fall) of the bell.

5.6 Absolute Filter. A filter or filter medium of ultra-high collection efficiency for very small particles (submicrometer size) so that essentially all particles of interest or of concern are collected. Commonly, the efficiency is 99.95% or higher for a standard aerosol of 0.3 μm diameter.

5.7 Calibration. The process of comparing a standard or instrument with one of greater accuracy (small uncertainty) to obtain quantitative estimates of the actual values of the standard being calibrated, the deviation of the actual value from a nominal value, or the difference between the value indicated by an instrument and the actual value.

5.8 Differential Pressure Meter. Any flow measuring device that operates by restricting air flow and measuring the pressure drop across the restriction.

5.9 Emissions. The total of substances discharged into the air from a stack, vent, or other discrete source.

5.10 Flowmeter. An instrument for measuring the rate of flow of a fluid moving through a pipe or duct system. The instrument is calibrated to give volume or mass rate of flow.

5.11 Impaction. A forcible contact of particles of matter. A term often used synonymously with impingement.

5.12 Impactor. A sampling device that employs the principle of impaction (impingement).

5.13 Impingement. The act of bringing matter forcibly in contact. As used in air sampling, refers to a process for the collection of particulate matter in which the gas being sampled is directed forcibly against a surface.

5.14 Inhalable Particles. Particles with aerodynamic diameters of $< 10 \mu\text{m}$ that are capable of being inhaled into the human lung.

5.15 Interference. An undesired positive or negative output caused by a substance other than the one being measured.

5.16 Mass Flowmeter. Device that measures the mass flow rate of air passing a point, usually using the rate of cooling or heat transfer from a heated probe.

5.17 Matter. The substance of which a physical object is composed.

5.18 Orifice Meter. A flowmeter, employing as the measure of flow rate the difference between the pressures measured on the upstream and downstream sides of the orifice (that is, the pressure differential across the orifice) in the conveying pipe or duct.

5.19 Aerodynamic Diameter (a.d.). The diameter of a unit density sphere having the same terminal settling velocity as the particle in question. Operationally, the size of a particle as measured by an inertial device.

5.20 Particle. A small discrete mass of solid or liquid matter.

5.21 Particulate. Solids or liquids existing in the form of separate particles.

5.22 Precision. The degree of mutual agreement between individual measurements, namely repeatability and reproducibility.

5.23 Pressure Gage. The difference in pressure existing within a system and that of the atmosphere. Zero gage pressure is equal to atmospheric pressure.

5.24 Rotameter. A device, based on the principle of Stoke's law, for measuring rate of fluid flow. It consists of a tapered vertical tube having a circular cross section, and containing a float that is free to move in a vertical path to a height dependent upon the rate of fluid flow upward through the tube.

5.25 Sampling. A process consisting of the withdrawal or isolation of a fractional part of a whole. In air or gas analysis, the separation of a portion of an ambient atmosphere with or without the simultaneous isolation of selected components.

5.26 Standard. A concept that has been established by authority, custom, or agreement to serve as a model or rule in the measurement of quantity or the establishment of a practice or procedure.

5.27 Traceability to NIST. Documented procedure by which a standard is related to a more reliable standard verified by the National Institute of Standards Technology (NIST).

5.28 Uncertainty. An allowance assigned to a measured value to take into account two major components of error: The systematic error and the random error attributed to the imprecision of the measurement process.

6. Apparatus Description

6.1 General Description

6.1.1 The essential features of a typical non size-specific TSP high-volume sampler are shown in Figure 1. The high volume sampler is a compact unit consisting of a protective housing; an electric motor driven; a high-speed, high-volume blower; a filter holder capable of supporting a 203 x 254-mm (8 in. by 10 in.) filter; and a flow-controller for controlling the air-flow rate through the instrument at 40-60 ft³/min.

6.1.2 In operation, this traditional TSP sampler draws ambient air into the sampler through the air inlet gap between the cover and the sampler housing walls (see Figure 2). The air inlet is uniform on all sides of the sampler to provide an effective particle capture air velocity between 20-35 cm/sec. at the recommended flow rate between 40-60 ft³/min. The gable roof design of the sampler allows the sampled air to be evenly distributed over the surface of a downstream filter, where TSP is collected.

6.1.3 For PM₁₀ measurement, the traditional gable roof of the TSP sampler is replaced with an impactor design size-select inlet, as illustrated in Figure 3. For the impactation design, an air sample enters a symmetrical (therefore wind-direction insensitive) hood and is deflected upward into a buffer chamber. The buffer chamber is evacuated at a rate of 68 m³/h (40 cfm) through multiple circular nozzles. Particles are accelerated as they pass through the nozzles to an impactation chamber (see Figure 4). Because of their momentum, particles having diameters larger than the inlet's 10-μm cut design impact the surface of the

impaction chamber. Smaller particles rise through the impaction chamber at speeds slow enough to minimize reentrainment of the impacted particles and then pass through multiple vent tubes to the high-volume sampler's filter where they are collected.

6.1.4 The second size-select design for PM_{10} measurement is the cyclone inlet, as illustrated in Figure 5. The omnidirectional cyclone used for fractionation in this inlet allows particles to enter from all angles of approach. An angular velocity component is imparted to the sample air stream and the particles contained in it by a series of evenly spaced vanes. Larger particle removal occurs in an inner collection tube. This tube incorporates a "perfect absorber," which is an oil-coated surface to eliminate particle bounce and reentrainment. The sample flow (with the unremoved smaller particles) then enters an intermediate tube, where the trajectory is altered to an upward direction. An additional turn is then made to alter the flow to a downward trajectory to allow the remaining particles (i.e., PM_{10} fraction) to deposit on a filter for subsequent analysis. As with the impaction inlet, control of air velocities in the cyclonic inlet is critical to maintain the correct particle size cutpoint. Maintaining the correct design volumetric flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, a popular cyclonic impaction inlet has a design flow rate of 1.13 m³/min.

6.2 Filter Medium

6.2.1 Selecting a filtration substrate for time-integrated SPM monitoring must be made with some knowledge of the expected characteristics and a pre-determined analytical protocol. For any given standard test method, the appropriate medium will normally be specified.

6.2.2 Of the various types of filters listed in Table 1 of Chapter IO-2 Overview, four general types of filter material have been used to capture SPM. They include cellulose fiber, quartz/glass fiber, mixed fiber and membrane filter types. Selecting a filter depends upon variables such as background metal content, artifact formation, and affinity for moisture. The basic characteristics of the types of filter material used in air monitoring are outlined in Table 1, while useful filter properties are identified in Table 2. Several characteristics are important in selection of filter media. They are:

- **Particle Sampling Efficiency.** Filters should remove more than 99% of SPM from the air drawn through them, regardless of particle size or flow rate.
- **Mechanical Stability.** Filters should be strong enough to minimize leaks and wear during handling.
- **Chemical Stability.** Filters should not chemically react with the trapped SPM.
- **Temperature Stability.** Filters should retain their porosity and structure during sampling.
- **Blank Correction.** Filters should not contain high concentrations of target compound analytes.

6.2.3 Quartz fiber filters are the most commonly used filters for SPM sampling for determining mass loading. Typical characteristics of quartz fiber filters are (1) a fiber content of high purity quartz, (2) a binder of below 5% (zero for binderless types), (3) a thickness of approximately 0.5 mm, (4) a surface with no pinholes, and (5) an allowance of no more than 0.05% of smoke particles to pass through the filter at a pressure of 100 mm of water with a flow rate of 8.53 m/min (28 ft/min), as determined by a DOP smoke test (see ASTM Method D2986).

6.2.4 Quartz fiber filters are made from finely spun glass fiber by combining the fiber with an organic binder and compressing this material in a paper machine. These filters are increasingly used in air sampling. These filters have the ability to withstand high temperatures (up to 540°C). They are further typified by high-collection efficiency. In some cases, the organic binder may interfere with subsequent analysis, so the filter is flash-fired to remove the binder material. This action causes some loss in tensile strength and usually requires that a backing material be used during sampling. The quartz filters are nonhygroscopic, thus allowing them to be used in areas where humidity is high. Because they are glass, they are the filter choice for most corrosive atmospheres. All the filters in this category are fragile and must be handled with care. Quartz fiber filters, because of the high silicate content, are extremely difficult to ash by chemicals or heat.

Therefore, extraction procedures are performed on these filters to remove the sample for subsequent chemical analysis. For this reason, flash-fired quartz filters are the major atmospheric sampling filters.

6.3 Flow Control System

The high-volume sampler employs two basic types of flow control systems. One is a mass-flow-control (MFC) system; the other is a volumetric-flow-control (VFC) system. Because the calibration and standard operating procedures differ considerably between these two types of flow-control systems, this method presents procedures that are control-system-specific. PM_{10} inlets can be used with either the MFC and VFC systems.

6.3.1 Mass-flow-control (MFC) system. The flow rate in a MFC system is actively sensed and controlled at a predetermined set point. Air is pulled through the filter into the intake of a blower and subsequently exits the sampler through an exit orifice, which facilitates measurement of the flow with a manometer or pressure recorder. The flow rate is controlled by an electronic mass-flow controller, which uses a flow sensor installed below the filter holder to monitor the mass flow rate and related electronic circuitry to control the speed of the motor accordingly to provide a constant sampling rate. The controlled flow rate can be changed by an adjustment knob on the flow controller.

6.3.2 Volumetric-flow-control (VFC) system. A VFC system maintains a constant volumetric flow rate through the inlet, rather than a constant mass flow rate as in the MFC system. In a popular commercial VFC system, a choked-flow venturi is operated such that the air attains sonic velocity in the throat of the device. In this "choked" mode, the flow rate is unaffected by downstream conditions, such as motor speed or exit pressure and is a predictable function of upstream conditions, such as the stagnation pressure ratio and temperature. Thus, the volumetric flow is controlled without any moving parts or electronic components. In this type of flow control system, no means is provided for adjusting the controlled flow rate. The controlled flow rate is set by the manufacturer through engineering design of the venturi.

7. Calibration

7.1 Introduction

[Note: All sampling equipment must be properly calibrated. Calibration is the relationship between an instrumental output and the input of a known reference standard. The objective of this section is to provide technically sound flow-rate calibration procedures for the MFC and VFC HV samplers.]

[Note: Consistency of temperature and barometric pressure is required. All temperatures should be expressed in kelvin ($K = ^\circ C + 273$). All barometric pressures should be expressed in mm Hg. Avoid calibrating an HV sampler using one set of units and then performing sample calculations using another set.]

7.1.1 HV sampler inlet. Two types of size-selective inlets available are impaction and cyclonic for monitoring inhalable particles ($< 10 \mu m$). The particle size discrimination characteristics of both the impaction and cyclonic type inlets depend critically on maintaining certain air velocities within the inlet; a change in velocity will result in a change in the nominal particle size collected. For this reason, the flow rate through the inlet must be maintained at a constant value that is as close as possible to the inlet's design flow rate. The design flow rate for a given sampler is specified in the sampler's instruction manual. The manual may also provide tolerance limits (or upper and lower limits) within which the sampler flow must be maintained. If the tolerance is not specified by the manufacturer, it should be assumed to be $\pm 10\%$.

7.1.1.1 The symmetrical design of the impaction inlet (see Figure 4) ensures wind-direction insensitivity. Ambient air that is drawn into the inlet is evacuated from the buffer chamber through nine acceleration nozzles into the first impaction chamber, where initial particle separation occurs. The air is then accelerated through an additional 16 jets into a second impaction chamber. The acceleration jets have critical diameters calculated by the manufacturer to provide the necessary changes in velocity to effect correct particle size fractionation within the impaction chambers. The air flow finally exits the inlet through nine vent tubes onto a sample filter. Because air velocities are critical to maintain the correct particle size cutpoint within the inlet, maintaining the correct design flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, the design flow rate for one popular impaction inlet is 1.13 m³/min.

7.1.1.2 The omnidirectional cyclone inlet (see Figure 5) used for fractionation allows particles to enter from all angles of approach. A angular velocity component is imparted to the sample air stream and the particles contained in it by a series of evenly spaced vanes. Larger particle removal occurs in an inner collection tube. This tube incorporates a "perfect absorber," an oil-coated surface to eliminate particle bounce and reentrainment. The sample flow (with the unremoved smaller particles) then enters an intermediate tube, where the trajectory is altered to an upward direction. An additional turn is then made to alter the flow to a downward trajectory to allow the remaining particles (i.e., PM₁₀ fraction) ultimately to deposit on a filter for subsequent analysis. As with the impaction inlet, control of air velocities in the cyclonic inlet is critical to maintain the correct particle size cutpoint. Maintaining the correct design volumetric flow rate through the inlet is important. This design flow rate is specified by the manufacturer in the instruction manual. For example, as in the case of the impaction inlet, a popular cyclonic inlet also has a design flow rate of 1.13 m³/min.

7.1.2 Total suspended particulate (TSP). As illustrated in Figure 2, particles of less than 100 µm are collected at a flow rate of 1.13-1.70 m³/min (40-60 ft³/min) using the conventional high-volume sampler, without size selection.

7.2 Summary of Calibration Procedures

[Note: During calibration, a closure plate perforated with a number of circular orifices is connected to the inlet of the sampler. The pressure drop across this orifice plate provides a measure of instrument air flow rate at any time. This pressure drop may be indicated by a rotameter, manometer, or other pressure-responsive device traceable to an NIST certified standard.]

7.2.1 A simple and sufficiently accurate method of calibrating is to compare the sampler meter with an orifice meter (working standard) that has been calibrated against a primary or master standard such as a Roots meter.

7.2.2 The preferable primary standard is a Roots meter of sufficient capacity to allow an accurate time-volume reading, which would be at least 30 s.

7.2.3 A positive displacement pump or blower may be used as a master flow-rate standard. In this case, the delivery rate of the master standard must be known accurately and the equipment must be in sound mechanical condition (no bypass leakage).

7.3 Certification of an Orifice Transfer Standard

[Note: The following certification procedure is applicable to an orifice transfer standard such as those that have been used previously in the calibration of both the traditional HV sampler and the PM₁₀ samplers. Two common types of orifice devices are available: one equipped with a set of fixed resistance plates (e.g., a reference flow [Ref] device or a top-hat orifice) and one with an externally variable resistance valve. The

series of plates normally provided by the orifice manufacturer include an 18-, 13-, 10-, 7-, and 5-hole plate. Unfortunately, the 5-hole plate provides too low a flow rate to be useful for HV calibration, and other plates may produce flow rates substantially outside the design flow-rate range of the commercially available HV inlets. One may opt to fabricate or procure a different series of resistance ranges or use the variable-resistance type orifice device.]

7.3.1 Orifice Calibration Procedure.

7.3.1.1 Assemble the following equipment (see Figure 6):

- Orifice transfer standard (i.e., top-hat orifice, variable orifice, or ReF device) to be calibrated.
- Water or oil manometer with a 0-400 mm (0-16") range and minimum scale divisions of 1 mm (0.1"). This manometer should be permanently associated with the orifice transfer standard.
- Variable voltage transformer, a set of resistance plates, or available flow orifice (see Figure 7).
- Calibrated positive displacement, standard volume meter (such as a Roots Meter®) traceable to National Institute of Standards and Technology (NIST).

[Note: As they are sold, standard volume meters may not be traceable to NIST. Traceability can be established directly through NIST or indirectly through the meter manufacturer's repair department. Periodic recertification is not normally required under clean service conditions unless the meter has been damaged and must be repaired. In general, damage will be indicated by a substantial (e.g., 50%) increase in the pressure drop across the meter. The meter's traceability certificate should contain a graph of the pressure drop as a function of flow rate.]

- High-volume air mover (e.g., a blower motor from a HV sampler).
- Accurate stopwatch.
- Mercury manometer, with a 0-200 mm (0-8") range and minimum scale divisions of 1 mm (0.1").
- Thermometer, capable of accurately measuring temperatures over the range of 0-50°C (273-323 K) to the nearest $\pm 1^\circ\text{C}$ and referenced to an NIST or ASTM thermometer within $\pm 2^\circ\text{C}$ at least annually.
- Barometer, capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg (66-106 kPa) to the nearest mm Hg and reference within ± 5 mm Hg of a barometer of known accuracy at least annually.
- Orifice transfer standard certification worksheet (see Figure 8).

7.3.1.2 Record on the orifice transfer standard certification worksheet the standard volume meter's serial number; orifice transfer standard's type, model, and serial number; the person performing the certification; and the date.

7.3.1.3 Observe the barometric pressure and record it as Pa. Read the ambient temperature in the vicinity of the standard volume meter and record it as Ta ($K = ^\circ\text{C} + 273$).

7.3.1.4 Connect the orifice transfer standard to the inlet of the standard volume meter. Connect the mercury manometer to measure the pressure at the inlet of the standard volume meter. Connect the orifice (water or oil) manometer to the pressure tap on the orifice transfer standard. Connect a high-volume air mover to the outlet side of the standard volume meter. Make sure that all gaskets are present and are in good condition.

7.3.1.5 Check that the standard volume meter table is level and adjust its legs if necessary.

7.3.1.6 Check for leaks by temporarily clamping both manometer lines (to avoid fluid loss) and blocking the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Start the high-volume air mover and note any change in the standard volume meter's reading. The reading should

remain constant. If the reading changes, locate any leaks by listening for a whistling sound and/or retightening all connections, making sure that all gaskets are properly installed.

[Note: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime; it can raise temperatures to the point of defeating the electrical insulation which could result in fire or electric shock to the user.]

7.3.1.7 After satisfactorily completing the leak check, turn off the high-volume air sampler, unblock the orifice, and unclamp both manometer lines. Zero the water and mercury manometers by sliding their scales so that their zero lines are even with the bottom of the menisci.

7.3.1.8 Turn on the high-volume air sampler. Adjust the variable voltage transformer to achieve an appropriate flow rate (i.e., within the approximate range of 0.9-1.3 m³/min (32-46 ft³/min)). If necessary, use fixed resistance plates or the variable resistance valve to achieve the appropriate flow rate (see Figure 7). The use of fixed resistance plates is discouraged (but not prohibited) because the leak check must be repeated each time that a plate is installed.

7.3.1.9 After setting a flow rate, allow the system to run for at least 1 min to attain a constant motor speed. Observe the standard volume meter dial reading and simultaneously start the stopwatch. Error in reading the meter dial can be minimized by starting and stopping the stopwatch on whole number dial readings (e.g., 4091.00).

7.3.1.10 Record the initial volume that the meter dial indicated when the stopwatch was started. Maintain this constant flow rate until at least 3 m³ of air have passed through the standard volume meter. Record the standard volume meter's inlet pressure manometer reading as • Hg and the orifice manometer reading as • H₂O. If • H₂O changes significantly during the run, abort the run and start again.

7.3.1.11 When at least 3 m³ of air have passed through the system, note the standard volume meter reading and simultaneously stop the stopwatch. Record the final volume that the meter dial was indicating when the stopwatch was stopped. Record the elapsed time (Time) indicated on the stopwatch.

7.3.1.12 Calculate the volume measured by the standard volume meter (Vol.) using the following equation:

$$\bullet \text{ Vol.} = \text{Final Volume} - \text{Initial Volume}$$

7.3.1.13 Correct this volume to ambient atmosphere pressure.

$$V_a = \bullet \text{ Vol.} (P_a - \bullet \text{ Hg})/P_a$$

where:

- V_a = actual volume at ambient barometric pressure, m³.
- $\bullet \text{ Vol.}$ = actual volume measured by the standard volume meter, m³.
- P_a = ambient barometric pressure during calibration, mm Hg.
- $\bullet \text{ Hg}$ = differential pressure at inlet to volume meter, mm Hg.

7.3.1.14 Calculate the actual volumetric flow rate (m³/min).

$$Q_a = V_a / \bullet \text{ Time}$$

where:

- Q_a = actual volumetric flow rate through the orifice, m^3/min .
• time = elapsed time, min.

7.3.1.15 Repeat Sections 7.3.1.8 through 7.3.1.14 for at least four additional flow rates within the approximate range of $0.9\text{--}1.3 \text{ m}^3/\text{min}$ ($32\text{--}46 \text{ ft}^3/\text{min}$). At least five evenly distributed different flow rates are required, and at least three flow rates must be in the specified inlet flow-rate interval ($1.02\text{--}1.24 \text{ m}^3/\text{min}$ [$36\text{--}44 \text{ ft}^3/\text{min}$]). Better calibration precision may be obtained by running additional flow rates or repeating the flow rates.

7.3.1.16 For each flow, compute $[(\bullet \text{ H}_2\text{O})(T_a/P_a)]^{1/2}$, and plot these values against the corresponding values of Q_a . Draw the orifice transfer standard's certification curve. For the model $[(\bullet \text{ H}_2\text{O})(T_a/P_a)]^{1/2} = m(Q_a) + b$, calculate the linear least squares regression's slope (m), intercept (b), and correlation coefficient (r) of the certification relationship. Plot the regression line on the same graph as the calibration data, as illustrated in Figure 9. A certification graph should be readable to $0.02 \text{ m}^3/\text{min}$.

7.3.1.17 If any calibration point does not fall within $\pm 2\%$ of the line, rerun the point, recalculate, and replot.

7.3.1.18 For subsequent use of the orifice transfer standard, calculate Q_a from the calibration relationship as:

$$Q_a(\text{orifice}) = \{[(\bullet \text{ H}_2\text{O})(T_a/P_a)]^{1/2} - b\} \{1/m\}$$

where:

- $Q_a(\text{orifice})$ = actual volumetric flow rate as indicated by the orifice transfer standard, m^3/min
• H_2O = pressure drop across the orifice, mm H_2O .
 T_a = ambient temperature during use, K ($K = \text{°C} + 273$).
 b = intercept of the orifice calibration relationship.
 m = slope of the orifice calibration relationship.

7.3.2 Orifice Transfer Standard Calibration Frequency. Upon receipt and at 1-yr intervals, the calibration of the orifice transfer standard should be certified with a standard volume meter (such as a Roots Meter®) traceable to NIST. An orifice transfer standard should be visually inspected for signs of damage before each use and should be recalibrated if the inspection reveals any nicks or dents.

7.4 Procedure for a Mass-Flow-Controlled (MFC) High Volume Sampler

The MFC sampler calibration procedure presented in this section relates known flow rates to the pressure in the exit orifice plenum. The known flow rates are determined by an orifice transfer standard that has been certified according to the procedure presented in Section 7.3.1. The exit orifice plenum is the area within the motor housing (below the motor unit) that contains the air flow just before it is exhausted to the atmosphere through the exit orifice. This exit orifice plenum pressure should be measured with a 25-cm (10") water or oil manometer. Also, each sampler should have its own dedicated manometer, which can be conveniently mounted to the side of the sampler housing. Other types of pressure measurement devices may be used provided they have comparable accuracy. The 4" continuous pressure (flow) recorders of the type often supplied with high volume PM_{10} samplers are generally not sufficiently accurate and are not recommended for quantitative sampler pressure or flow measurements. These flow recorders should be used only for nonquantitative determination that the flow was approximately constant and uninterrupted over the sample period. The flow recorder may be connected in parallel with the manometer or other pressure

measuring device, using a tee or "y" tubing connection. For this MFC calibration procedure, the following conditions are assumed:

- The high volume PM₁₀ sampler is equipped with a mass flow controller to control its sample flow rate.
- The sampler flow rate is measured by measuring the exit orifice plenum pressure, using a water or oil manometer [or, if necessary, a continuous-flow recording device using square-root-scale chart paper].
- The transfer standard for the flow-rate calibration is an orifice device equipped with either a series of resistance plates or an integral variable-resistance valve. The pressure drop across the orifice is measured by an associated water or oil manometer.

[Note: Because flow recorders are still widely used for quantitative flow measurements, the calibration procedure includes specific instructions for quantitatively calibrating a flow recorder. These flow recorder instructions are enclosed in brackets [] and should be used only when a manometer or other pressure measurement device cannot be used.]

7.4.1 Calibration Equipment.

7.4.1.1 Orifice transfer standard with calibration traceable to NIST (see Section 7.3).

7.4.1.2 An associated water or oil manometer, with a 0-400 mm (0-16") range and an minimum scale division of 2 mm (0.1")

[Note: Digital manometers may also be used in place of water or oil manometers, especially in cold/frigate climates. Ensure the battery in the manometer is new before use.]

7.4.1.3 A water or oil manometer, with a 0-400 mm (0-16") range and a minimum scale division of 2 mm (0.1") for measurement of the sampler exit orifice plenum pressure. This manometer should be associated with the sampler.

[Note: Manometers used for field calibration may be subject to damage or malfunction and should thus be checked frequently.]

7.4.1.4 Thermometer, capable of accurately measuring temperature over the range of 0-50°C (273-323 K) to the nearest $\pm 1^\circ\text{C}$ and referenced to an NIST or ASTM thermometer within $\pm 2^\circ\text{C}$ at least annually.

7.4.1.5 A portable aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg (66-106 kPa) to the nearest mm Hg and referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.

7.4.1.6 Miscellaneous handtools, calibration data sheets or station log book, and 51 mm (2") duct tape.

7.4.2 Multipoint Flow-Rate Calibration. The procedure presented here is basic and generic, given the assumptions listed in Section 7.4. More detailed calibration procedures, variations, or alternative procedures may be presented in the manufacturer's instruction manual. The manual should be reviewed carefully and the various calibration variations or alternative procedures should be evaluated. In-house equipment and personnel, procedural simplicity and uniformity, and subsequent data applications should be considered in establishing the specific, detailed calibration procedure to be implemented.

[Note: Do not attempt to calibrate the MFC sampler under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of pressure variations.]

7.4.2.1 Set up the calibration system as recommended by the manufacturer. A typical MFC PM₁₀ sampler calibration configuration is illustrated in Figure 10. MFC samplers are calibrated without a filter or filter cassette installed.

7.4.2.2 Disconnect the motor from the flow controller and plug it directly into a stable line voltage source (i.e., the sampler's on-off timer, if so equipped, or other source of the line voltage).

7.4.2.3 Install the orifice transfer standard and its adapter faceplate on the sampler. Check all gaskets and replace any questionable ones.

[Note: Tighten the faceplate nuts evenly on alternate corners to properly align and seat the gaskets. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.]

7.4.2.4 Select the first calibration flow rate and install the appropriate resistance plate or adjust the variable orifice valve. At least four flow rates are required to define the calibration relationship. For resistance plate orifices, make sure that the orifice and resistance plate gaskets are in place and the orifice is not cross-threaded on the faceplate.

7.4.2.5 To leak check, block the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Seal the pressure port with a rubber cap or similar device. Turn on the sampler. Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. A leak-free system will not produce an upscale response in the sampler's exit orifice manometer or flow recorder. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by cross-threading of the orifice transfer standard on the faceplate. All leaks must be eliminated before proceeding with the calibration. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

[Note: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime and can raise temperatures to the point of defeating the electrical insulation, which could result in fire or electric shock to the user.]

7.4.2.6 Inspect the connecting tubing of both manometers for crimps or cracks. Open the manometer valves (if present) and blow gently through the tubing, watching for the free flow of the fluid. Adjust the manometers' sliding scales so that their zero lines are at the bottom of the menisci. Connect the orifice transfer standard manometer to the orifice transfer standard. Connect the sampler's exit orifice manometer [and the continuous-flow recorder, if used] to the exit orifice plenum port. Ensure that one side of each manometer is open to atmospheric pressure. Make sure that the tubing fits snugly on the pressure ports and on the manometer.

7.4.2.7 If a continuous flow recorder is to be used quantitatively in lieu of a manometer, record the site location, sampler S/N, date, and the operator's initials on the blank side of a clean recorder chart. Make sure the chart has a square-root scale. Open the front door of the sampler and install the clean recorder chart.

7.4.2.8 Read and record the following parameters on the HV data sheet. An example calibration data sheet for the MFC sampler is illustrated in Figure 11.

- Date, location, and operator's signature.
- Sampler S/N and model.
- Ambient Pa, mm Hg.
- Ambient temperature (Ta), K ($K = ^\circ C + 273$).
- Orifice S/N and calibration relationship.

[Note: Consistency of temperature and barometric pressure units is required. All temperatures should be expressed in kelvin ($K = ^\circ C + 273$). Also, all barometric pressures should be expressed in mm Hg. Avoid calibrating a sampler using one set of units and then performing sampler calculations using another set.]

[Note: Ideally, the temperature of the air in the exit orifice plenum should be measured because it will be somewhat higher than ambient temperature. However, an adequate approximation of this temperature may be obtained by adding 30 K to the ambient temperature. This addition is incorporated in the calculations given in Section 7.4.3.]

7.4.2.9 Turn on the sampler and allow it to warm up to operating temperature (3-5 min). Then read and record the orifice transfer standard's manometer deflection, \bullet H₂O (in. H₂O), and the corresponding sampler's manometer deflection, \bullet Pex [or flow recorder chart reading, I].

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom for air flow and for the manometer tubing.]

7.4.2.10 Install the other resistance plates or adjust the variable orifice value to obtain each of the other calibration flow rates and repeat Section 7.4.2.9 for each. At least four calibration flow rates are required.

7.4.2.11 Plot the calibration data on a sheet of graph paper as specified in Section 7.4.3.4.

[Note: The data should be plotted in the field as the calibration is occurring, rather than afterwards back at the laboratory.]

Repeat Section 7.4.2.9 for any data that are questionable on the plot.

[Note: Running additional calibration points at differing flow rates or repeating the calibration points at the same flow rates is encouraged to improve the precision of the calibration.]

7.4.2.12 Turn off the sampler and remove the orifice transfer standard.

7.4.2.13 Reconnect the sampler motor to the flow controller.

7.4.2.14 Perform the calibration calculations presented in the following section. The data generated will be used to set the mass flow controller (see Section 7.4.4) to a value that will result in optimal volumetric flow based on the seasonal average temperature and barometric pressure at the monitoring site.

7.4.3 Calibration Calculations. Gather all calibration data, including the orifice calibration information and the sampler calibration data sheet (and, if used, the flow recorder chart, which should graphically display the various calibration flow rates).

[Note: These calculations should be done at the time of the calibration, rather than later. This approach will allow additional calibration points to be taken if questions arise about the data that have already been obtained.]

7.4.3.1 Verify that the orifice transfer standard calibration relationship is current and traceable to an acceptable primary standard.

7.4.3.2 Calculate and record Q_a for each calibration point from the orifice calibration information using the following equation.

$$Qa(\text{orifice}) = \{ \bullet \cdot H_2O(Ta/Pa) \}^{1/2} - b \} \{1/m\} \text{ where:}$$

$Qa(\text{orifice})$ = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min

- H_2O = pressure drop across the orifice, in. H_2O .
- Ta = ambient temperature during use, K ($K = \bullet C + 273$).
- Pa = ambient barometric pressure during use, mm Hg.
- b = intercept of the orifice calibration relationship.
- m = slope of the orifice calibration relationship.

7.4.3.3 Calculate and record the quantity for each calibration point as:

$$\bullet \cdot P_{ext} = [\bullet \cdot P_{ex}(Ta + 30)/Pa]^{1/2}$$

where:

- P_{ext} = transformed manometer reading.
- P_{ex} = sampler manometer reading, in. H_2O Ta = ambient temperature, K ($K = \bullet C + 273$).
- Pa = ambient barometric pressure, mm Hg.

[If a continuous-flow recorder is used quantitatively, calculate and record the quantity $[It]$ as follows:

$$[It] = I[Ta + 30]/Pa^{1/2}$$

where:

- $[It]$ = transformed flow recorder chart reading.
- I = flow recorder chart reading, arbitrary units on square root scale.

[*Note: If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for I in the above equation.*]

7.4.3.4 On a sheet of graph paper, plot the calculated $Qa(\text{orifice})$ flow rates on the x-axis and the transformed sampler manometer response, $\bullet \cdot P_{ext}$ [or the transformed flow recorder reading, $[It]$], on the y-axis.

Because determining the sampler's average operational flow rate (Qa) during a sample period depends on the ambient average temperature and pressure, using a graphic plot of the calibration relationship is not recommended for subsequent data reduction. This plot is used only to visually assess the calibration points to see if any should be rerun. Plot the regression line on the same graph paper as the calibration data. For the regression model $y = mx + b$, let $y = 2 \bullet \cdot P_{ext}$ and $x = Qa(\text{Orifice})$ so that the model is given by:

$$\bullet \cdot P_{ext} = m[Qa(\text{orifice})] + b$$

For the flow recorder, the model is:

$$It = m[Qa(\text{orifice})] + b]$$

Using a programmable calculator or a calculation data form, determine the linear regression slope (m), intercept (b), and correlation coefficient (r) and record them on the data sheet. A five-point calibration should yield a regression equation with a correlation coefficient of $r > 0.990$, with no point deviating more

than $\pm 0.04 \text{ m}^3/\text{min}$ from the value predicted by the regression equation. Plot the regression line on the same graph paper that has the individual calibration points.

7.4.3.5 For subsequent sample periods, the sampler's average actual operational flow rate, $\overline{Q_a}$, is calculated from the calibration slope and intercept using the equation.

$$\overline{Q_a} = \{ \cdot \overline{P_{ex}} (T_{av} + 30)/P_{av} \}^{1/2} - b \} \{1/m\}$$

where:

- $\overline{Q_a}$ = the sampler's average actual flow rate, m^3/min .
- $\overline{P_{ex}}$ = average of initial and final sampler manometer readings ($\cdot P_{ex_i} + \cdot P_{ex_f}$), mm Hg.
- T_{av} = average ambient temperature for the sample period, K ($K = \cdot C + 273$).
- P_{av} = average ambient pressure for the sampling period, mm Hg.
- b = intercept of the sampler calibration relationship.
- m = slope of the sampler calibration relationship.

[For the flow controller,

$$\overline{Q_a} = \{ \overline{I} (T_{av} + 30)/P_{av} \}^{1/2} - b \} \{1/m\}$$

where:

\overline{I} = average flow recorder reading for the sample period.]

[*Note: If recorder charts with linear scales are used, substitute $(I)^{1/2}$ for (I) in the above equation.*]

7.4.4 Mass Flow Controller Adjustment Procedure. The controlled flow rate of an MFC sampler is adjustable and must be set to the proper design flow rate. The constant mass flow maintained by the MFC causes the actual volumetric flow rate through the inlet to fluctuate as the ambient temperature and barometric pressure change at the monitoring site. Normally, the range of these fluctuations is within the allowable tolerance limits for the inlet. However, the flow-rate set point of the mass flow controller must be correctly adjusted so that the deviations are "centered" with respect to the seasonal average temperature and barometric pressure at the site, not the temperature and pressure prevailing at the time of setting. The correct seasonal volumetric setpoint flow rate (SFR) at T_a and P_a has had the same mass flow rate as the inlet design volumetric flow rate at T_s and P_s .

[*Note: The correct SFR may differ from day to day and may be somewhat higher or lower than the inlet design flow rate on any particular day.*]

7.4.4.1 Determine the seasonal average temperature (T_s) and seasonal average pressure (P_s) at the site and record them on the calibration data sheet. (Determination of the number of "seasons," i.e., the number of different seasonal average temperatures needed for the year, is left to the discretion of the operator.)

7.4.4.2 Calculate SFR and record on the calibration data sheet:

$$\text{SFR} = (1.13) (P_s/P_a)(T_a/T_s)$$

where:

SFR = set-point actual volumetric flow rate for adjustment of the mass flow controller, based on seasonal average temperature and average pressure at site, m³/min.

1.13 = inlet design flow rate (as specified by the manufacturer), m³/min.

P_s, P_a = seasonal average and current ambient barometric pressure at the site, respectively, mm Hg.

T_s, T_a = seasonal average and current ambient temperature, respectively, K (K = °C + 273).

7.4.4.3 Calculate and record on the sampler's calibration data sheet the sampler set-point manometer reading [or flow recorder reading] that corresponds to the SFR calculated in Section 7.4.4.2.

$$\text{SSP} = [P_a/(T_a + 30)][m(\text{SFR}) + b]^2$$

where:

SSP = sampler set-point manometer reading, in H₂O.

P_a = ambient barometric pressure, mm Hg.

T_a = ambient temperature, K (K = °C + 273).

m = slope of the sampler's calibration relationship.

SFR = set-point flow rate from 7.4.4.2, m³/min.

b = intercept of the sampler's calibration relationship.

[For the flow recorder,

$$\text{SSP} = [m(\text{SFR}) + b] [P_a/(T_a + 30)]^{1/2}]$$

7.4.4.4 Visually check to make sure the motor is connected to the mass flow controller and the manometer is properly connected.

7.4.4.5 Install a clean filter (in a filter cassette) in the sampler according to the manufacturer's instructions. [If the continuous flow recorder is used quantitatively, install a clean chart and verify that the recorder is zeroed (i.e., the pen rests on the innermost circle of the chart).]

7.4.4.6 Turn on the sampler and allow it to warm up to operating temperature (3-5 min).

7.4.4.7 Following the manufacturer's instructions, adjust the mass flow controller until the manometer reading [or flow recorder response] indicates the sampler set point (SSP) as calculated in Section 7.4.4.3.

7.4.4.8 Verify that the flow controller will maintain this flow rate for at least 10 min. Turn off the sampler.

7.4.4.9 The sampler can now be prepared for the next sample run day.

7.5 Procedure for a Volumetric-Flow-Controlled (VFC) Sampler

The VFC sampler calibration procedure presented in this section relates known flow rates (Q_a, as determined by an orifice transfer standard) to the ratio of the stagnation pressure to the ambient barometric pressure (P_i/P_a). The stagnation pressure (P_i) is the air pressure inside the sampler in the area just under the filter. VFC samplers have a stagnation pressure tap or port through which the stagnation pressure can be measured. A VFC sampler may also have an exit orifice below the motor similar to those in MFC samplers. In this case, the sampler flow rate can be measured and calibrated using the exit orifice plenum pressure generally described in Section 7.4. However, using the stagnation pressure generally provides a more accurate

indication of sampler flow rate. Additionally, a continuous-flow recorder may be connected to the exit orifice pressure tap for nonquantitative determination that the flow rate was constant and uninterrupted over the sample period.

The stagnation pressure should be measured with a 0-1000 mm (0-36") oil, water, or digital manometer. Also, each sampler should have its own dedicated manometer, which can be conveniently mounted to the side of the sampler housing. Other types of pressure measurement instruments may be used provided they have comparable accuracy. However, the 4" continuous pressure (i.e., flow) recorders often supplied with HV samplers are generally not sufficiently accurate and are **not recommended** for quantitative sampler pressure or flow rate measurements.

The VFC sampler's flow control system is a choke-flow venturi. This system must be precisely sized for a given average annual temperature and pressure because no means is provided for the user to adjust the operational flow rate. Therefore, the purchasing agency should notify the manufacturer of the **operational** location of the sampler; differences in temperature and pressure between the shipping address and the monitoring site may result in an incorrect operational flow rate. As with the MFC sampler, both the ambient temperature and barometric pressure readings must be determined or estimated during the sampling period for the subsequent calculation of total sampler volume in standard volume units.

For this VFC calibration procedure, the following conditions are assumed:

- The VFC sampler uses a choked-flow venturi to control the actual volumetric flow rate.
- The sampler flow rate is measured by measuring the stagnation pressure ratio, and the sampler is not equipped with a continuous flow recorder.
- The sampler inlet is designed to operate at a constant actual volumetric flow rate of 1.13 m³/min.
- The transfer standard for the flow-rate calibration is an orifice device equipped with either a series of resistance plates or an integral variable-resistance valve. The pressure drop across the orifice is measured by an associated water or oil manometer.
- The sampler will be calibrated in actual volumetric flow-rate units (Qa), and the orifice transfer standard is also calibrated in Qa, as specified in Section 7.3.

7.5.1 Calibration Equipment.

7.5.1.1 Orifice transfer standard with proper calibration traceable to NIST (see Section 7.3).

7.5.1.2 An associated water, oil, or digital manometer, with a 0-400 mm (0-16") range and minimum scale divisions of 2 mm (0.1").

7.5.1.3 An oil, water, or digital manometer, with a 0-1000 mm (0-36") range and minimum scale divisions of 2 mm (0.1") or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other pressure instrument) should be associated with the sampler.

[Note: Manometers used for field calibration may be subject to damage or malfunction and should thus be checked frequently.]

7.5.1.4 Thermometer, capable of accurately measuring temperature over the range of 0-50°C (273-323 K) to the nearest ±1°C and referenced to an NIST or ASTM thermometer within ±2°C at least annually.

7.5.1.5 A portable, aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg to the nearest mm Hg and referenced within ±5 mm Hg to a barometer of known accuracy at least annually.

7.5.1.6 Calibration data sheets or the station log book and 51 mm (2")-wide duct tape.

7.5.1.7 A clean filter.

7.5.2 Multipoint Flow-Rate Calibration Procedure - VFC Sampler. The procedure presented here is basic and intended to be generic, given the assumptions listed in Section 7.5. More detailed calibration procedures, variations, or alternative procedures may be presented in the manufacturer's instruction manual. The manual should be reviewed carefully and that the various calibration variations or alternative procedures be evaluated. In-house equipment and personnel, procedural simplicity and uniformity, and subsequent data applications should be considered in establishing the specific, detailed calibration procedure to be implemented.

[Note: The calibration of some VFC samplers may be affected by changes in line voltage, particularly if the line voltage is below normal (normal is about 115 V). For this reason, VFC samplers should always be calibrated at the monitoring site. Further, if the line voltage at the site is low and likely to fluctuate significantly, a line voltage booster or regulator may be advisable. Also, be sure that replacement blower motors are of the correct type.]

[Note: Do not attempt to calibrate the VFC sampler under windy conditions. Short-term velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The calibration will be less precise because of the pressure variations.]

7.5.2.1 Set up the calibration system as recommended by the manufacturer. A typical VFC sampler calibration configuration is illustrated in Figure 12. The VFC sampler manufacturer may specify that the sampler be calibrated with a filter installed, which generally precludes calibration flow rates higher than normal operating flow rate. Additional calibration flow rates obtained without a filter may be appropriate, as discussed in Section 7.5.2.8.

7.5.2.2 Install the orifice transfer standard and its adapter faceplate on the sampler. First inspect all gaskets and seals and replace any doubtful ones.

[Note: Tighten the faceplate nuts evenly on alternate corners to properly align and uniformly seat the gaskets. The nuts should be hand-tightened only; too much compression can damage the sealing gasket.]

7.5.2.3 Select a calibration flow rate and install the appropriate resistance plate (or no plate) or adjust the variable resistance valve. At least four flow rates are required to define the calibration relationship. At least three flow rates should be within the acceptable flow-rate range (i.e., 1.02-1.24 m³/min) for the sampler inlet. For resistance plate orifices, make sure the orifice and resistance plate gaskets are in place and the orifice is not cross-threaded on the faceplate.

7.5.2.4 Leak check the system by blocking the orifice with a large-diameter rubber stopper, wide duct tape, or other suitable means. Seal the pressure port with a rubber cap or similar device. Turn on the sampler. Gently rock the orifice transfer standard and listen for a whistling sound that would indicate a leak in the system. Leaks are usually caused either by a damaged or missing gasket between the orifice transfer standard and the faceplate or by crossthreading of the orifice transfer standard on the faceplate. All leaks must be eliminated before proceeding with the calibration. When the system is determined to be leak-free, turn off the sampler and unblock the orifice.

[Note: Avoid running the sampler for longer than 30 s at a time with the orifice blocked. This precaution will reduce the chance that the motor will be overheated due to the lack of cooling air. Such overheating can shorten the motor's lifetime. It can raise temperatures to the point of defeating the electrical insulation, which could result in fire or electric shock to the user.]

7.5.2.5 Inspect the connecting tubing of the manometers for crimps or cracks. Open the manometer valves (if present) and blow gently through the tubing, watching for the free flow of the fluid. Adjust the manometers' sliding scales so that their zero lines are at the bottom of the menisci. Connect the transfer standard manometer to the transfer standard and the sampler stagnation pressure manometer (or other pressure instrument) to the stagnation pressure port. Ensure that one side of each manometer is open to atmospheric pressure. Make sure the tubing fits snugly on the pressure ports and on the manometers.

7.5.2.6 Read and record the following parameters on the VFC Sampler Data Sheet. An example calibration data sheet for the VFC sampler is illustrated in Figure 13.

- Date, location, and operator's signature.
- Sampler S/N and model.
- Ambient barometric pressure (Pa), mm Hg.
- Ambient temperature (Ta), °C and K ($K = °C + 273$).
- Orifice S/N and calibration relationship.

[Note: Consistency of temperature and barometric pressure units is required. All temperatures should be expressed in kelvin ($K = °C + 273$). Also, all barometric pressures should be expressed in mm Hg. Avoid calibrating a HV sampler using one set of units and then performing sampler calculations using another set.]

7.5.2.7 Turn on the sampler and allow it to warm to operating temperature (3-5 min). Read and record the orifice transfer standard's manometer reading, H_2O , and the corresponding sampler relative stagnation pressure manometer reading, Pstg, on the data sheet. (Relative stagnation pressure is a negative pressure [i.e., a vacuum] relative to atmospheric pressure as measured by a manometer with one leg open to the atmosphere.) Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the calibration data sheet:

$$\text{mm Hg} = 25.4 (\text{in. } H_2O/13.6)$$

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom of air flow and for the manometer tubing.]

7.5.2.8 Install the other resistance plates or adjust the variable orifice value to obtain each of the other calibration flow rates and repeat Section 7.5.2.7 for each. At least four calibration flow rates are required with at least three in the acceptable flow-rate range. Difficulties may be encountered in obtaining flow rates in the acceptable range. Even with modified resistance plates (or with no plates) installed, it may be impossible to obtain three acceptable flow rates with a filter mounted on the sampler. Lower flow rate calibration points may be used by extrapolation into the acceptable range without a filter installed in the sampler. If additional calibration points are obtained without a filter, they should be examined carefully to make sure they are consistent with the calibration points obtained with a filter (i.e., they fall on a smooth curve through all the calibration points).

7.5.2.9 Plot the calibration data on a sheet of graph paper as specified in Section 7.5.3.5 of the next section. Repeat Section 7.5.2.7 for any data that are questionable on the plot. Running additional calibration points at differing flow rates or repeating the calibration points at the same flow rates is encouraged to improve the precision of the calibration.

[Note: The data should be plotted in the field as the calibration is occurring, rather than afterwards back at the laboratory.]

7.5.2.10 Turn off the sampler and remove the orifice transfer standard.

7.5.2.11 Install a clean filter on the sampler in the normal sampling mode (use a filter cassette if one is normally used). Turn on the sampler and allow it to warm up to operating temperature.

7.5.2.12 Read the relative stagnation pressure as in Section 7.5.2.7 and record it on the data sheet in the row for the operational flow rate.

7.5.2.13 Perform the calibration calculations presented in the following sections.

7.5.3 Calibration Calculations. Gather together all the calibration data, including the orifice transfer standard's calibration information and the sampler calibration data sheet.

[Note: These calculations should be done at the time of the calibration, rather than later. This approach will allow additional calibration points to be taken if questions arise about the data that have already been obtained.]

7.5.3.1 Verify that the orifice transfer standard calibration relationship is current and traceable to an acceptable primary standard.

7.5.3.2 Calculate the record $Q_a(\text{orifice})$ for each calibration point from the orifice calibration information and the equation.

$$Q_a(\text{orifice}) = \{[\bullet \text{ H}_2\text{O}(T_a/P_a)]^{1/2} - b\} \{l/m\}$$

where:

$Q_a(\text{orifice})$ = actual volumetric flow rate as indicated by the transfer standard orifice, m^3/min .

• H_2O = pressure drop across the orifice, in. H_2O .

T_a = ambient temperature during use, K ($K = ^\circ\text{C} + 273$).

P_a = ambient barometric pressure during use, mm Hg.

b = intercept of the orifice transfer standard's calibration relationship.

m = slope of the orifice transfer standard's calibration relationship.

7.5.3.3 Calculate and record the value of the absolute stagnation pressure ratio, $[PI]$, for each calibration point:

$$[PI] = P_a - \bullet \text{ Pstg}$$

where:

$[PI]$ = absolute stagnation pressure, mm Hg.

P_a = ambient barometric pressure, mm Hg.

• Pstg = relative stagnation pressure, mm Hg.

7.5.3.4 Calculate and record the stagnation pressure ratio:

$$\text{Stagnation pressure ratio} = PI/P_a$$

7.5.3.5 On a sheet of graph paper, plot the calculated orifice transfer standard's flow rates, $Q_a(\text{orifice})$, on the x-axis vs. the corresponding stagnation pressure ratios, PI/P_a , on the y-axis. Draw a smooth curve through the plotted data. If necessary, extrapolate the curve to include the acceptable flow-rate range.

7.5.3.6 If the sampler manufacturer has provided a factory calibration table (i.e., the lookup table) for the sampler, compare $Q_a(\text{orifice})$ for several points on the calibration plot with $Q_a(\text{sampler})$ determined from the factory calibration. Calculate the percentage difference between $Q_a(\text{orifice})$ and $Q_a(\text{sampler})$ using the following equation.

$$\% \text{ Difference} = \frac{Q_a(\text{sampler}) \cdot Q_a(\text{orifice})}{Q_a(\text{orifice})} \cdot [100]$$

If the agreement is within a few (i.e., 2 or 4) percent, the factory calibration is validated and may be used for subsequent sample periods. Proceed to Section 7.5.5.

7.5.3.7 If the agreement is not within a few percentage points, recheck the accuracy of the orifice transfer standard and recheck the calibration procedure. Look for leaks, manometer reading errors, incorrect temperature or pressure data, or miscalculations. Also check for abnormally low line voltage at the site (it should be at least 110 V ac), for the correct blower motor, and for the presence of a gasket between the motor and the choked-flow venturi. A factory calibration is not likely to be substantially incorrect, and any discrepancy of more than a few percent is probably due to some problem with the sampler or with the calibration procedure. However, if no errors or problems with the sampler or with the calibration can be found, or if no factory calibration is provided by the manufacturer, proceed as described in Section 7.5.4.

7.5.4 Generation of Calibration Relationship - VFC Sampler.

7.5.4.1 For each calibration point, calculate and record the quantity,

$$[(P/P_a)T_a]^{1/2}$$

where:

P/P_a = stagnation pressure ratio from the equation in Section 7.5.3.

T_a = ambient temperature during sampler calibration, K ($K = ^\circ C + 273$).

7.5.4.2 For the general linear regression model, $y = mx + b$, let $y = [(P/P_a)T_a]^{1/2}$ and let $x = Q_a(\text{orifice})$, such that the model is given by:

$$[(P/P_a)T_a]^{1/2} = m[Q_a(\text{orifice})] + b$$

Calculate the linear regression slope (m), intercept (b), and correlation coefficient (r).

[Note: Inspect the plotted calibration curve to determine whether any of the calibration points that are substantially outside of the acceptable flow-rate range need to be eliminated so that they do not result in an inappropriate linear regression line.]

7.5.4.3 For subsequent sample periods, the sampler's average actual operating flow rate, Q_a , is calculated from the calibration slope and intercept using the following equation.

$$\overline{Q_a}(\text{sampler}) = \{[\overline{P/P_a}T_{av}]^{1/2} - b\} \{1/m\}$$

where:

$\overline{Q_a}(\text{sampler})$ = the sampler's average actual flow rate, m^3/min .

$\overline{P/P_a}$ = average stagnation pressure ratio for the sampling period.

T_{av} = average ambient temperature for the sampling period, K ($K = ^\circ C + 273$).

b = intercept of the sampler calibration relationship.

m = slope of the sampler calibration relationship.

[*Note: The average value for PI should be calculated from stagnation pressure measurements taken before and after the sampling period. Pav should be estimated from barometric pressure for the sampling period. See also Section 9.4 for additional information.*]

7.5.4.4 If a calibration (Lookup) table is desired, evaluate the above equation for various appropriate values of PI/Pa and Ta and list the corresponding values of Qa(sampler) in tabular form.

7.5.5 Single-Point Operational Flowrate Ventilation. This procedure compares the VFC sampler's normal operating flow rate to the design flow rate of the inlet (e.g., 1.13 m³/min).

7.5.5.1 Determine the value of PI/Pa for the operational flow rate obtained with only the filter cassette installed (see Section 7.5.2.11 and Section 7.5.2.12).

7.5.5.2 Determine the new sampler flow rate, Qa(sampler) from the lookup table that corresponds to this value of PI/Pa. Use the manufacturer's calibration table if it has been validated in 7.5.3.6; otherwise, use the equation in Section 7.5.4.3.

7.5.5.3 Compare Qa(sampler) with the inlet design flow rate (e.g., 1.13 m³/min) using the following equation:

$$\text{Design flow rate\% difference} = \frac{Qa(\text{sampler}) \cdot 1.13}{1.13} \times 100$$

This design flow rate percentage difference must be less than the allowable flow rate tolerance (i.e., ± 10 , if not otherwise specified by the manufacturer). However, this value should be well within ± 7 to allow for some variation with ambient temperature. If this value is not within ± 7 , recheck the calibration procedure and data for errors. Check the sampler for leaks, bad motor brushes, missing gaskets, incorrect motor type, or abnormally low line voltage. Because the VFC flow rate is not adjustable, the VFC manufacturer must be consulted to resolve cases of substantially incorrect VFC flow rates.

7.6 Sampler Calibration Frequency

To ensure accurate measurement calibrate HV samplers upon installation and recalibrate as follows:

7.6.1 At least quarterly or annually (see 40 CFR 58, Appendix A for a description of the quality assurance requirements);

7.6.2 After any repairs that might affect sampler calibration (e.g., replacing the motor);

7.6.3 After relocation of the sampler to a different site;

7.6.4 If the results of a field flow-check exceed quality control limits (e.g., greater than $\pm 7\%$ from the sampler's indicated flow rate); or

7.6.5 Whenever a field flow-check or performance audit indicates that the sampler is out (or nearly out) of the acceptable flow-rate range.

[*Note: Multipoint flow-rate calibrations should be distinguished from single-point, quality control flow checks (see Section 13). The latter are done more frequently than calibrations and are intended to check if the sampler flow rate, Qa(sampler), or the calibration relationship has changed significantly since the last calibration.*]

8. Filters

8.1 Pre-weighing of Filters

8.1.1 Filters ready for field use have been pre-weighed in the laboratory, under prescribed climate control conditions of temperature and relative humidity, using Inorganic Compendium Method IO-3.1, *Selection, Extraction and Preparation of Filter Material*.

8.1.2 Within Method IO-3.1, the user is provided guidance on proper selection of filter material in order to meet project specific data quality objectives (DQOs), how to visually inspect a new lot of filters for consistency and identification of defects, and initial weighing of the filters so a net concentration of particulate matter can be calculated after sampling.

8.1.3 The user should follow the procedures outlined within Method IO-3.1 as part of meeting the program's standard operating procedures (SOPs) and quality control (QC) requirements.

8.2 Filter Handling

8.2.1 Filter material may be brittle and subject to shearing and breakage. Laboratory and field personnel must be aware of these characteristics and handle sample filters with care.

8.2.2 For convenience, filters can be packed in groups of 50 or less in their original containers or in a box of comparable size. The filters should be separated by a sheet of 8 ½ x 11" tracing paper. Filter inventory can be controlled by stacking the filters in numerical order so that the operator will use the proper filter first. One side of the shipping box can be cut away to allow the operator to remove the filter easily without damaging the corners.

8.2.3 A filter identification number must be assigned to each filter. Because of difficulty in seeing the "up" side (i.e., the side with the slightly rougher texture) of the filter, consistency in labeling these filters will allow the operator easy access to the filter ID number for documentation and cross-referencing laboratory data forms. This consistency will also eliminate confusion in loading the filter cassettes for subsequent sampling. If the filter ID number is embossed by the operating agency, gentle pressure must be used to avoid filter damage, and extreme care must be taken to avoid duplication or missed numbers.

8.2.4 If samples are to be mailed, the field operator should be supplied with reinforced envelopes and manila folders for protection of the exposed filters during their return to the analytical laboratory. These manila folders may be printed to serve as sample data sheets.

8.3 Visual Filter Inspection

All filters must be visually inspected for defects, and defective filters must be rejected if any are found. Batches of filters containing numerous defects should be returned to the supplier.

The following are specific defects to look for:

- **Pinhole** - a small hole appearing as a distinct and obvious bright point of light when examined over a light table or screen, or as a dark spot when viewed over a black surface.
- **Loose material** - any extra loose material or dirt particles on the filter that must be brushed off before the filter is weighed.
- **Discoloration** - any obvious visible discoloration that might be evidence of a contaminant.
- **Filter nonuniformity** - any obvious visible nonuniformity in the appearance of the filter when viewed over a light table or black surface that might indicate gradations in porosity across the face of the filter.
- **Other** - a filter with any imperfection not described above, such as irregular surfaces or other results of poor workmanship.

9. Sampling Procedure

[Note: This section describes routine operation of a monitoring site using an HV sampler and covers an array of topics, ranging from initial site selection to final data documentation. The procedures herein are intended to serve as guidelines for developing a monitoring program that will accurately reflect trends in local or regional air quality. The effectiveness of the monitoring program depends on responsible day-to-day operation of the monitoring site. The operators who conduct sampling activities offer a unique perspective on the sampler's performance, and their awareness and attention to detail will salvage data that may otherwise be lost. Note, however, that "routine" does not mean "unimportant." The site operator provides cohesiveness in a sampling program.]

9.1 Summary

9.1.1 The PM₁₀ sampler can be used in a number of ways. Procedure variations may include the kind of filter medium, the surface area of the filter, prescreening to exclude particles up to a given size, and the manner of placing and exposing the filter during the test. The procedure most commonly used will be described here.

9.1.2 Calibrate the sampler as described in the Section 7. Do not make any change or adjustment on the sampler flow indicator after calibrating. Remove the calibrating orifice. The filters may be packed into a box with sheets of glassine between the filters, or they may be individually packed in self-sealing plastic bags for transportation to the field.

9.1.3 Mount the filter sheet in the filter holder taking care not to lose any of the fiber. Clamp it in place by means provided. Seal into place easier by facing the smooth side into the housing if there is a difference in texture. If the filter holder is separate from the sampler, mount the holder on the intake port, making sure that the coupling gasket is in place and that it is tight.

9.1.4 Place the sampler in the position and location called for in the test, which is with the filter face up, in a horizontal plane, and inside a housing. The dimensions and clearances specified are intended to provide uniformity in sampling practice.

9.1.5 Start the sampler motor and record the time and date. Read the flow-rate indicator and record this reading and the corresponding flow rate as read from the calibration curve. Note also the temperature and barometric pressure. An electric clock should be connected to the same line as the motor so as to detect any loss of test time due to power interruption. A continuous record of the sampling flow rate and sampling time can be obtained by the use of a continuous pressure (or flow rate) recorder.

9.1.6 Allow the sample to run for the specified length of time, which is commonly 24 h, ± 1 h. During this period several readings of flow rate, temperatures, barometric pressure, and time should be taken if this is feasible. A final set of reading is taken at the end of the test period. If only initial and final readings are made, assume that change of readings is linear over the period of test. Intermediate readings will improve the accuracy of volume measurement.

9.1.7 At the end of the sampling period, record all final readings. Remove the filter from the mount very carefully so as not to lose any of the fiber material or collected particulate matter. Fold the filter in half upon itself with the collected material enclosed within. Place the folded filter in a clean tight envelope and mark it for identification. In some applications it may be desirable to place the used filter in a tight metal container to prevent any loss or damage to the filter.

9.1.8 In the laboratory remove the filter from its container. Tap the container and knock any loose fiber or particulate matter onto the inside surface of the folded filter. Examine the inside surface and, with a pair of tweezers, remove any accidental objects such as insects.

9.2 Siting Requirements

9.2.1 As with any type of air monitoring study in which sample data are used to draw conclusions about a general population, the validity of the conclusions depends on the representativeness of the sample data. Therefore, the primary goal of a monitoring project is to select a site or sites where the collected particulate mass is representative of the monitored area.

9.2.2 Basic siting criteria for the placement of high-volume sampler (either TSP or PM₁₀) are documented in Table 3. This list is not a complete listing of siting requirements; instead, an outline to be used by the operating agency to determine a sampler's optimum location. Complete siting criteria are presented in 40 CFR 58, Appendix E.

9.2.3 Additional factors not specified in the Code of Federal Regulations (CFR) must be considered in determining where the sampler will be deployed. These factors include accessibility under all weather conditions, availability of adequate electricity, and security of the monitoring personnel and equipment. The sampler must be situated where the operator can reach it safely despite adverse weather conditions. If the sampler is located on a rooftop, care should be taken that the operator's personal safety is not jeopardized by a slippery roof surface during inclement weather. Consideration also should be given to the fact that routine operation (i.e., calibrations, filter installation and recovery, flow checks, and audits) involves transporting supplies and equipment to and from the monitoring site.

9.2.4 To ensure that adequate power is available, consult the manufacturer's instruction manual for the sampler's minimum voltage and power requirements. Lack of a stable power source can result in the loss of many samples because of power interruptions.

9.2.5 The security of the sampler itself depends mostly on its location. Rooftop sites with locked access and ground-level sites with fences are common. In all cases, the security of the operating personnel as well as the sampler should be considered.

9.3 Sampler Installation Procedures

9.3.1 On receipt of a high-volume sampler (TSP or PM₁₀) from the manufacturer, visually inspect it and account for all components. Compare the equipment delivered with the enclosed packing slip. Notify the manufacturer immediately of any missing or damaged equipment.

9.3.2 Perform a laboratory check to determine if the sampler is operational. Turn on the sampler and observe the vacuum motor performance and shift the recorder response (if so equipped).

9.3.3 Carefully transport the sampler to the field site. If possible, install the sampler in the center of the site platform. This practice will ensure easy access to the sampler's inlet during maintenance procedures and will reduce inlet damage if the sampler should topple over.

9.3.4 Following manufacturer's instructions, carefully assemble the base and inlet of the sampler. The sampler must be bolted down to a secure mounting surface.

9.3.5 Check all tubing and power cords for crimps, cracks, or breaks.

9.3.6 Plug the power cord into a line voltage outlet. If possible, this outlet should be protected by a ground fault interrupter (GFI) for the operator's safety. The use of waterproof interlocking electrical connectors is also recommended to ensure operator safety and to avoid shorts or power interruptions. Do not allow any electrical connections to be submerged during periods of inclement weather.

9.3.7 Turn on the sampler and make sure that it is still working properly. Investigate and correct any malfunctions before proceeding. Operate the sampler for approximately 30 min to ensure that the motor brushes are properly seated and that the motor is operating at full performance.

9.3.8 Perform a multipoint flow-rate calibration, as described in Section 7.

9.4 Sampling Operations

9.4.1 General.

9.4.1.1 Operational procedures will vary according to the sampler model and options (e.g., the types of flow-rate controller and timer) selected for use in the monitoring program. Consult the instrument manual before putting the sampler into operation. Significant differences exist in the field operation of the two types of flow-controlling systems and, hence, in the determination of operational flow rates. The following assumptions are made in this section:

- The flow rate through a sampler that is equipped with a mass-flow controller is indicated by the exit orifice plenum pressure. This pressure is measured with a manometer (or a flow recorder).
- The flow rate through a sampler that is equipped with a volumetric-flow controller is indicated by the stagnation pressure. This pressure is measured with a manometer.
- The sampler has been calibrated according to procedure presented in Section 7.

9.4.1.2 The sampler has been calibrated according to procedures presented in Section 7.

9.4.1.3 The average actual flow rate for MFC samplers is calculated by determining the following:

- The average of the initial and final manometer readings of the exit orifice plenum pressure (or the average flow recorder reading).
- The average ambient temperature (T_{av}).
- The average ambient barometric pressure (P_{av}) during the sampling period.

These values are then applied to the sampler's calibration relationship. The 4" pressure flow recorders often supplied with HV samplers generally are not sufficiently accurate and are *not recommended* for quantitative sampler pressure or flow rate measurements. These flow recorders should be used only for nonquantitative determination that the flow was approximately constant and uninterrupted over the sampling period. The flow recorder may be connected in parallel with the manometer or other pressure measuring device using a tee or "Y" tubing connector.

[Note: Because flow recorders are still widely used for quantitative flow rate measurements, the procedures in this section include specific instructions for the use of a flow recorder. These flow recorder instructions are enclosed in brackets.]

9.4.1.4 The average actual flow rate for VFC samplers is calculated by determining the following:

- The average of the initial and final relative stagnation pressures (P_{stg}).
- The average ambient temperature (T_{av}).
- The average barometric pressure (P_{av}) during the sampling period and then by applying these values to the calibration relationship.

[Note: Consistency of temperature and barometric pressure units is required. All temperatures should be expressed in kelvin ($K = ^\circ C + 273$). Also, all barometric pressures should be expressed in either mm Hg or kPa (but don't mix the two units). Avoid calibrating a PM_{10} sampler using one set of units and then performing sample calculations using another set.]

9.4.2 Presampling Filter Preparation Procedures.

9.4.2.1 Most high-volume samplers (TSP or PM_{10}) have been designed to accept filter cassettes. Loading these cassettes in the laboratory will minimize damage; however, if extreme care is exercised, they can be loaded at the site when ambient conditions permit. Wear protective gloves when handling filters to avoid contaminating the filters with body oils and moisture. Keep the filters in protective folders or boxes. Never bend or fold unexposed filters. The analytical laboratory (and/or filter manufacturer) will give each filter an ID number. Because it is extremely difficult to see the "up" side of a quartz filter (i.e., the side with the slightly rougher texture), the filters should be consistently labeled on one side. When a filter that has

been labeled on its "down" side is folded for transport to the laboratory, its sample number will be readily accessible for documentation on laboratory log sheets upon arrival at the laboratory.

9.4.2.2 Following the manufacturer's instructions, carefully load the pre-weighted filter in the filter cassette. The filter should be centered on the wire screen so that the gasket will form an airtight seal on the outer edge of the filter when the faceplate is in place. Poorly aligned filters show uneven white borders after exposure. Care should be taken to ensure that the filter cassette is not excessively tightened, as the filter may stick or the gasket may be permanently damaged. Check that the gasket is in good condition and has not deteriorated.

9.4.3 Sampling Procedures--MFC Sampler.

9.4.3.1 Filter Installation Procedure.

9.4.3.1.1 Following the manufacturer's instructions, loosen the nuts that secure the inlet to the base and gently tilt back the inlet to allow access to the filter support screen.

9.4.3.1.2 Examine the filter support screen. If the screen appears dirty, wipe it clean. If the filter cassette is equipped with a protective cover, remove it and place the loaded cassette in position on the sampler support screen. Tighten the thumb nuts to hold the filter cassette securely. Check that the gasket is in good condition and has not deteriorated.

Caution: Tighten the thumb nuts evenly on alternate corners to properly align and seat the gasket. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

9.4.3.1.3 If an inlet is being used, lower the sample inlet. Inspect the sample inlet to make sure that it is resting on the filter cassette and not on the sampler's frame. Secure the sample inlet to the sampler base.

9.4.3.1.4 Open the front door of the sample and examine the flow recorder. Remove any moisture inside by wiping it with a clean cloth. Record the sampler S/N, filter ID number, site location, and sampling data on the back of a clean chart and install the chart in the flow recorder.

[Note: Charts used for PM_{10} samplers normally have square-root-function scales; however, linear-function scales may be used. If charts with linear-function scales are used, Equations in Section 7.4.3.3 and Section 7.4.3.5 will have to be modified from their current form by replacing I with $(I)^{1/2}$]

[Note: While installing the chart, do not bend the pen arm beyond its limits of travel. Raise the pen head by pushing on the very top of the pen air (or by using the pen lift). Be sure that the chart tab is centered on the slotted drive to ensure full 360° rotation in 24 h. Make sure that the chart edges are properly located beneath the retainers. Lower the pen arm and tap the recorder face lightly to make certain that the pen is free.]

[Note: During periods of inclement weather, the chart tends to stick to the recorder face. Two charts can be installed simultaneously to enable the sample (top, annotated) chart to rotate freely.]

9.4.3.1.5 Using a coin or slotted screwdriver, advance the chart and check to see that the pen rests on zero--the smallest circle diameter. If necessary, adjust the zero set screw while gently tapping on the side of the flow recorder. If a chart with a linear function scale is used, some positive zero offset may be desirable to allow for normal variation in the zero readings.

9.4.3.1.6 Turn on the sampler and allow it to equilibrate to operating temperature (3-5 min).

9.4.3.1.7 While the sampler is equilibrating, record the following parameters on the MFC Sampler Field Data Sheet (see Figure 14):

- Site Location.
- Sample date.
- Filter ID number.
- Sampler model and S/N.
- Operator's initials.

9.4.3.1.8 Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer while watching for the free flow of the fluid. Adjust the manometer's sliding scale so that its zero line is at the bottom of the menisci.

9.4.3.1.9 Measure the initial exit orifice plenum pressure (Pex) using an oil or water manometer, with a 0-200-mm (0-8") range and a minimum scale division of 1 mm (0.1"). Record the initial Pex on the MFC Sampler Field Data Sheet. If Pex is substantially different than for previous samples or otherwise appears abnormal, carry out a Quality Control (QC) flow check as described in Section 13.1.

9.4.3.1.10 Verify that the flow recorder (if used) is operational and that the pen is inking. Note the flow recorder reading. If it is substantially different than for previous samples or otherwise appears abnormal, carry out a QC flow-check as described in Section 13.1.

9.4.3.1.11 Turn the sampler off.

9.4.3.1.12 Check the time indicated by the time-set pointer on the flow recorder. If it is in error, rotate the chart clockwise by inserting a screwdriver or coin in the slotted drive in the center of the chart face until the correct time is indicated.

9.4.3.1.13 Reset the elapsed time meter to 0000 min and the sampler timer for the next run day. Close the sampler door, taking care not to crimp the vacuum tubing or any power cords. The sampler is now ready to sample ambient air.

9.4.3.2 Filter Recovery Procedure. As soon as possible after sampling, the operator should return to the monitoring site to retrieve the exposed filter. Particle loss or filter damage will result if the filter is left in the sampler for extended periods.

9.4.3.2.1 Turn on the sampler and allow it to equilibrate to operating temperature (3-5 min).

9.4.3.2.2 Measure the final Pex and record it on the MFC Sampler Field Data Sheet.

9.4.3.2.3 Turn off the sampler.

9.4.3.2.4 Open the door of the sampler, remove the flow recorder chart, and examine the recorder trace. If the trace indicates extensive flow fluctuations, investigate and correct before the next sampling day.

9.4.3.2.5 Record the following parameters on the MFC Sampler Field Data Sheet:

- Elapsed time of the sampling period, min.
- Average recorder response, arbitrary units.
- Average ambient temperature for the run day (Tav), K ($K = ^\circ C + 273$).
- Average ambient barometric pressure for the run day (Pav), mm Hg or kPa.

[Note: Tav and Pav readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level), and they may have to be corrected for differences between the evaluation are not available, seasonal average temperature (Ts) and barometric pressure (Ps) may be substituted for Tav and Pav, respectively. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. Therefore, seasonal values may represent actual values within 20°C and 40 mm Hg.]

The calculations presented in this section assume that the sampler has been calibrated in terms of actual temperature and barometric pressure and that the substitution of seasonal values is used only to determine the sampler's operational flow rate during a sample period. Although additional calculations to convert the sampler's calibration curve to seasonal can be made, the error represented by this method is negligible.

9.4.3.2.6 Calculate and record the average actual flow rate (as determined by the sampler's calibration relationship) on the MFC Sampler Field Data Sheet and on the back of the chart. Attach the chart to the data sheet.

$$Q_a = \{ [\bar{P}_{ex} (T_{av} + 30)/P_a]^{1/2} - b \} \{1/m\}$$

or for the flow recorder,

$$\bar{Q}_a = \{ [\bar{I} (T_{av} + 30)/P_a]^{1/2} - b \} \{1/m\}$$

where:

- \bar{Q}_a = average sampler flow rate, actual m³/min.
- \bar{P}_{ex} = average exit orifice plenum pressure, mm Hg.
- I = average flow recorder response, arbitrary units.
- T_{av} = average ambient temperature for the run day, K.
- P_{av} = average ambient pressure for the run day, mm Hg.
- b = intercept of the MFC sampler calibration relationship.
- m = slope of the MFC sampler calibration relationship.

[Note: If charts with linear-function scales are used, substitute $(I)^{1/2}$ for I .]

9.4.3.2.7 Observe conditions around the monitoring site; note any activities that may affect filter particle loading (e.g., paving, mowing, fire) and record this information on the MFC Sampler Field Data Sheet.

9.4.3.2.8 Raise the sampler inlet and remove the filter cassette. Replace the cassette protective cover (if so equipped). To avoid particle loss, be careful to keep the cassette as level as possible.

9.4.3.2.9 The sampler may now be readied for the next run day.

9.4.3.2.10 Keeping the filter cassette level, carefully transport it, the data sheet, and the flow recorder chart to the laboratory sample custodian.

9.4.4 Sampling Procedures--VFC Sampler.

9.4.4.1 Filter Installation Procedure.

9.4.4.1.1 Following the manufacturer's instructions, loosen the nuts that secure the inlet to the base and gently tilt back the inlet to allow access to the filter support screen.

9.4.4.1.2 Examine the filter support screen. If the screen appears dirty, wipe it clean. If the filter cassette is equipped with a protective cover, remove it and place the loaded cassette in position on the sampler support screen. Tighten the thumb nuts sufficiently to hold the filter cassette securely. Check that the gasket is in good condition and has not deteriorated.

Caution: Tighten the thumb nuts evenly on alternate corners to properly align and seat the gasket. The nuts should be only hand-tightened because too much compression can damage the sealing gasket.

9.4.4.1.3 If an inlet is used, lower the sample inlet and secure it to the sampler base. For impaction inlets, inspect the sample inlet to make sure that it is resting on the filter cassette and not on the sampler's frame. Secure the sampler inlet to the sampler base.

9.4.4.1.4 Record the following parameters on the VFC Sampler Field Data Sheet (see Figure 15):

- Site location.
- Sample date.
- Filter ID number.
- Sampler model and S/N.
- Operator's initials.

9.4.4.1.5 Turn on the sampler and allow it to reach a stable operating temperature (3-5 min).

9.4.4.1.6 Bring an oil or water manometer to the side of the sampler. This manometer should have a range of 0-400 mm (0-16") and a minimum scale division of 1 mm (0.1").

[Note: Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the VFC Sampler Field Data Sheet.]

$$\text{mm Hg} = (25.4) (\text{in. H}_2\text{O}/13.6)$$

Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer, while watching for the free flow of the fluid.

Adjust the manometer's sliding scale so that its zero line is at the bottom of the menisci.

9.4.4.1.7 Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the connecting tubing, attach one side of the manometer to the port. Leave the other side of the manometer open to atmospheric pressure. Make sure the tubing snugly fits the port and the manometer.

9.4.4.1.8 Measure the initial relative stagnation pressure (\bullet Pstg) and record this reading on the VFC Sampler Field Data Sheet.

9.4.4.1.9 Turn off the sampler, disconnect the manometer, and replace the vacuum cap on the stagnation pressure port.

9.4.4.1.10 Reset the elapsed-time meter to 0000 min and the sampler timer for the next run day. The sampler is now ready to sample ambient air.

9.4.4.2 Filter Recovery Procedure. As soon as possible after sampling, the operator should return to the monitoring site to retrieve the exposed filter. Particle loss or filter damage will result if the filter is left in the sampler for extended periods.

9.4.4.2.1 Turn on the sampler and allow it to warm up to operating temperature (3-5 min).

9.4.4.2.2 While the sampler is equilibrating, record the following parameters on the VFC Sampler Field Data Sheet:

- Elapsed time of the sampling period, min.
- Average ambient temperature for the run day (T_{av}), \bullet C and K.
- Average ambient barometric pressure for the run day (P_{av}), mm Hg.

[Note: T_{av} and P_{av} readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office, National Weather Service (NWS) station, or an airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport. If T_{av} and P_{av} readings are not available, seasonal average temperature (T_s) and barometric pressure (P_s) can be substituted. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. Therefore, seasonal values may represent actual values within 20 \bullet C and 40 mm Hg.]

9.4.4.2.3 Inspect the manometer for crimps or cracks in its connecting tubing. Open the valves and blow gently through the tubing of the manometer, while watching for the free flow of the fluid. Adjust the manometer sliding scale so that its zero line is at the bottom of the meniscuses.

9.4.4.2.4 Remove the vacuum cap from the stagnation pressure port located on the side of the sampler base. Using the connecting tubing, attached one side of the manometer to the port. Make sure that the tubing snugly fits the port and the manometer. Leave the other side open to atmospheric pressure.

9.4.4.2.5 Record the final Pstg on the VFC Sampler Field Data Sheet. Turn off the sampler and replace the vacuum cap.

[Note: Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the Sampler Field Data Sheet.]

$$\text{mm Hg} = 25.4 (\text{in. H}_2\text{O}/13.6)$$

9.4.4.2.6 Calculate the average relative stagnation pressure ($\overline{\bullet \text{Pstg}}$) and record it on the data sheet.

9.4.4.2.7 Calculate the average absolute stagnation pressure ($\overline{\text{PI}}$) for the sample run day and record it on the data sheet.

$$\overline{\text{PI}} = \text{Pav} - \overline{\bullet \text{Pstg}}$$

where:

$\overline{\text{PI}}$ = average absolute stagnation pressure, mm Hg.

Pav = average ambient barometric pressure for the run day (not the retrieval day), mm Hg.

$\bullet \text{Pstg}$ = average stagnation pressure drop, mm Hg.

9.4.4.2.8 Calculate and record the average stagnation pressure ratio:

$$\text{Average stagnation pressure ratio} = \text{PI}/\text{Pav}$$

where:

PI = average absolute stagnation pressure, mm Hg.

Pav = average ambient barometric pressure on the sample run day, mm Hg.

9.4.4.2.9 Using the manufacturer's lookup table (or an alternate calibration relationship as described in Section 7.5.4), locate the column and row corresponding to $\overline{\text{PI}}/\text{Pav}$ and the Tav value for the sample run day. Read and record the indicated $\overline{\text{Qa}}$ value.

9.4.4.2.10 Observe conditions around the monitoring site; note any activities that may affect filter particle loading (paving, mowing, fire) and record this information on the VFC Sampler Field Data Sheet.

9.4.4.2.11 Raise the sampler inlet and remove the filter cassette. Replace the cassette protective cover (if so equipped). To avoid particle loss, be careful to keep the cassette as level as possible.

9.4.4.2.12 The sampler may now be readied for the next sampling period.

9.4.4.2.13 Keeping the filter cassette level, carefully transport it and the Sampler Field Data Sheet to the laboratory sample custodian.

9.4.5 Post-Sampling Filter Handling Procedures. If a sample will not be analyzed immediately, the sample custodian should store the filter within a protective covering. Because filter cassettes often prove too expensive and unwieldy for storage purposes, the use of a manila folder and a protective envelope of comparable size to that of the filter is recommended. Laboratory personnel should adhere to the following procedure:

9.4.5.1 Following the manufacturer's instructions, remove the top frame of the filter cassette.

9.4.5.2 Conduct a secondary check of a sample's validity as presented in "Laboratory Validation Criteria" (see Section 9.5).

9.4.5.3 Carefully slip a manila folder underneath the edge of the exposed filter. The filter may stick in the cassette because of overcompression of the filter cassette gasket. Be extremely careful to avoid damage to the brittle quartz filter.

9.4.5.4 Center the filter on the folder. If the filter must be touched, do not touch or jar the deposit. Fold the manila folder lengthwise at the middle with the exposed side of the filter in. If the collected sample is not centered on the filter (i.e., the unexposed border is not uniform around the filter), fold it so that only deposit touches deposit. **Do not crease the folder**--the sample filter may tear. If the filter shears or breaks, ensure that all pieces of the filter are included within the folder.

9.4.5.5 Insert the folder into the protective envelope.

9.4.5.6 Deliver the filter in its protective folder and envelope, accompanied by the completed data sheet, to the analytical laboratory.

9.5 Sample Validation and Documentation

9.5.1 Field Validation Criteria. After each sampling period, calculate the percentage difference between Q_a and the design flow rate (1.13 m³/min) using the following formula:

$$\% \text{ Difference} = 100 \frac{\overline{Q_a} \cdot 1.13}{1.13}$$

Record this value on a control chart for the field validation of the sampler's actual volumetric flow rate as is shown in Figure 16.

- Decreases in flow rate during sampling (due to mechanical problems) of more than 10% from the initial set point result in sample invalidation. Recalibrate the sampler. A sample flow rate may also fluctuate due to heavy filter loading. If a high concentration is suspected, the operator should indicate this on the field data sheet. The laboratory supervisor will make the final decision regarding the sample's validity.
- Changes in flow-rate calibration of more than 10%, as determined by a field QC flow-rate check (see Section 13), will invalidate all samples collected back to the last calibration or valid flow check. Recalibrate the sample.

9.5.2 Laboratory Validation Criteria.

9.5.2.1 Upon receiving the filter from the field, check the filter for signs of air leakage by observing the border around the filter. If the border is clear, then the gasket on the sampler is still usable. However, if particulate matter is on the border, then air leakage has occurred and the gasket on the sampler should be changed. Leakage may result from a worn or improperly installed faceplate gasket. A gasket generally deteriorates slowly. The sample custodian should be able to decide well in advance (by the increased fuzziness of the sample outline) when to change the gasket before total gasket failure results. If signs of leakage are observed, void the sample, determine the cause, and instruct the operator to take corrective actions before starting another sampling period.

9.5.2.2 Check the exposed filter for physical damage that may have occurred during or after sampling. Physical damage after sampling would not invalidate the sample if all pieces of the filter were put in the

folder; however, complete losses of loose particulate after sampling (e.g., loss when folding the filter) would void the sample. Mark such samples as "void" on the HV data sheet.

9.5.2.3 Check the appearance of the particles. Any changes from normal color may indicate new emission sources or construction activity in the area. Note any change on the data sheet.

9.5.2.4 The filters should be weighed according to the procedures described in Inorganic Compendium Method IO-3.1, Section 5, *Gravimetric Analysis*.

9.5.3 Data Documentation. Recordkeeping is a critical part of the QA program. Careful documentation of sampling data will salvage samples that may otherwise be lost. The sheer repetition of recording data may result in errors; however, this cross-referencing between data sheets, log books, and (for those samplers so equipped) the continuous-flow recorder charts will allow the operator to pinpoint discrepancies that may result in a sample's invalidation.

[Note: The use of log books at monitoring sites is highly encouraged.]

9.5.3.1 Presampling Documentation and Inspection. The following information should be recorded on the Sampler Field Data Sheet (SFDS), sampler recorder chart (RC), flow-rate control chart (CC), and in the site log book (LB):

- Site Location.
- Sample Date.
- Filter ID number.
- Sample model and S/N.
- Operator's initials.

9.5.3.2 Post-Sampling Documentation and Inspection. Upon receipt of exposed filters from the field, the sample custodian should adhere to the following procedures.

9.5.3.2.1 Examine the field data sheet. Determine whether all data needed to verify sample validity and to calculate mass concentration are provided (e.g., average flow rate, ambient temperature, barometric pressure, and elapsed time). Void the sample if data are missing or unobtainable from a field operator or if a sampler malfunction is evident.

9.5.3.2.2 If the exposed filter was packaged for shipment, remove the filter from its protective envelope and examine the shipping envelope. If sample material has been dislodged from a filter, recover as much as possible by brushing it from the envelope onto the deposit on the filter with a soft camel's-hair brush.

9.5.3.2.3 Match the filter ID number with the correct laboratory data/coding form on which the original balance ID number, filter ID number, filter tare weight, and other information are inscribed. The sample custodian should group filters according to their recorded balance ID numbers. Initial separation of filters by balance ID number will decrease the probability of a balance error that could result from the use of different balances for tare and gross weights.

9.5.3.2.4 Remove the filter from the protective manila folder. Should the filter be retained in its filter cassette, loosen the nuts on the top and remove the filter. Overtightening the nuts may cause the filter to adhere to the cassette gasket. Gently remove it by the extreme corners to avoid damage. Inspect the filters for any damage that may have occurred during sampling. Conduct a secondary check of a sample's validity (as presented in Section 9.4). If insects are embedded in the sample deposit, remove them with Teflon®-tipped tweezers and disturb as little of the sample deposit as possible. If more than 10 insects are observed, refer the sample to the supervisor for a decision on acceptance or rejection of the filter for analysis.

9.5.3.2.5 Place defect-free filters in protective envelopes and forward them to the laboratory for weighing and analysis. File the data sheets for subsequent mass concentration calculations.

9.5.3.2.6 Place defective filters, with the type of defect(s) listed, in separate clean envelopes. Label the envelopes and submit them to the laboratory supervisor for final approval of filter validity.

10. Interferences

10.1 Large extraneous objects, such as insects, may be swept into the filter.

10.2 Liquid aerosols, such as oil mists and fog droplets, are retained by the filter. If the amount of liquid so collected is sizeable, the filter can become wet and its function may be impaired.

10.3 Any gaseous or vaporous constituent of the atmosphere under test that is reactive with or absorbed on the filter will be retained.

10.4 As the filter becomes loaded with collected matter, the sampling rate is reduced. If a significant drop in flow rate occurs, the average of the initial and final flow rate will not give an accurate estimate of total flow during the sampling period. The magnitude of such errors will depend on the amount of reduction of airflow rate and on the variation of the mass concentration of dust with time during the 24-h sampling period. As an approximate guideline, any sample should be suspect if the final flow rate is less than one-half the initial rate.

10.5 Power failure or voltage change during the test period will lead to an error, depending on the extent and time duration of such failure.

10.6 The passive loading of the filter left in place for any time prior to or following a sampling period can introduce an error. The timely installation and removal of the filter is advisable, or a sampler with shutters may be used.

10.7 If two or more samplers are used at a given location, they should be placed at least 2 meters apart so that one sampler will not affect the results of an adjacent sampler.

10.8 Recent wind tunnel studies have shown significant possible sampling errors as a function of sampler orientation in atmospheres containing high relative concentrations of large particles.

10.9 Metal dusts from motors, especially copper, may significantly contaminate samples under some conditions.

10.10 Under some conditions, atmospheric SO₂ and NO_x may interfere. Artifact formation errors are caused by the retention of sulfur dioxide in the form of sulfate particulate on alkaline filters. Experiments involving a variety of filters indicate that sulfate loading errors of 0.3-3.0 µg/m³ can be expected with the use of common glass fiber filters under normal sampling conditions and that larger sulfate errors are possible under extreme sampling conditions. A neutral or low-alkalinity filter medium will eliminate excessive artifact formation.

10.11 Guidelines to help prevent post-sampling particle loss are presented in Section 8.

11. Calculations, Validations, and Reporting of TSP and PM₁₀ Data

11.1 Basic Information Used for Calculations

11.1.1 The design flow rate is specified as an actual volumetric flow rate (Q_a), measured at existing conditions of temperature (T_a) and pressure (P_a). The sampler's operational flow rate should be very close to the design flow rate. All samplers have some means for measuring the operational flow rate, and that flow rate measurement system must be calibrated periodically with a certified flow rate transfer standard. Usually, measurements (or estimates) of ambient temperature and barometric pressure are required to get an accurate indication of the operational flow rate. To determine the average sampler flow rate over a sample period, use the average temperature (T_{av}) and average barometric pressure (P_{av}) over the sample period. However, if average temperature and pressure values (or reasonable estimates) cannot be obtained for each sample period, seasonal average temperature (T_s) and barometric pressure (P_s) for the site may be substituted.

[Note: T_{av} and P_{av} readings may be recorded on site or estimated from data obtained from a nearby U.S. National Weather Service Forecast Office, NWS station, or local airport weather station. Barometric pressure readings obtained from airports or other sources must be at station pressure (i.e., not corrected to sea level), and they may have to be corrected for differences between the elevation of the monitoring site and that of the airport. If individual T_{av} and P_{av} readings cannot be obtained for each sample period and seasonal averages for the site are routinely substituted, care must be taken to ensure that the actual temperature and barometric pressure at the site are reasonably represented by such averages. Therefore, seasonal average temperature and pressure values (T_s and P_s) for the site by should be used only when these values are within 20 K and 40 mm Hg (5 kPa) of the actual average temperature and barometric pressure (T_{av} and P_{av}) for the sample period.]

11.1.2 The calculations presented in this section assume that the sampler has been calibrated in actual volumetric flow rate units (Q_a) and that individual average temperature and barometric pressure values are used for each sample period. If seasonal average temperature and pressure values for the site are to be used, T_s may be substituted for T_{av} , and P_s may be substituted for P_{av} .

11.1.3 The true or actual flow rate through the sampler inlet must be known and controlled. A common source of error in a monitoring program is confusion of various air volume flow-rate measurement units. Although the sampler's operational flow rate must be monitored in terms of actual volume flow rate units (Q_a), sampler flow rates can be corrected to standard volume flow rate units (Q_{std}) at EPA standard conditions of temperature (25°C) and pressure (760 mmHg).

- Q_a : Actual volumetric air flow rates, measured and expressed at existing conditions of temperature and pressure and denoted by Q_a (Q_{actual}). Typical units are L/min and m³/min. Inlet design flow rates for PM₁₀ samplers are always given in actual volumetric flow rate units.
- Q_{std} : Airflow rates that have been corrected to equivalent standard volume flow rates at EPA standard conditions of temperature and pressure (25°C or 298 K and 760 mm Hg or 101 kPa) and denoted by Q_{std} ($Q_{standard}$). Typical units are std. L/min, and std. m³/min. Standard volume flow-rate units are often used by engineers and scientists because they are equivalent to mass flow units.

11.1.4 The Q_a and Q_{std} measurement units must not be confused or interchanged. The flow-rate units can be converted as follows, provided the existing temperature and pressure (or in some cases the average temperature and pressure over a sampling period) are known:

$$\begin{aligned}\overline{Q_{std}} &= \overline{Q_a} (P_a/P_{std})(T_{std}/T_a) \\ Q_{std} &= (P_{av}/P_{std})(T_{std}/T_{av}) \\ Q_a &= Q_{std}(P_{std}/P_a)(T_a/T_{std})\end{aligned}$$

where:

- Q_{std} = standard volume flow rate, std m³/min.
- Q_a = actual volume flow rate, actual m³/min.
- P_a = ambient barometric pressure, mm Hg.
- P_{std} = EPA standard barometric pressure, 760 mm Hg.
- T_{std} = EPA standard temperature, 298 K.
- T_a = standard temperature, K (K = °C + 273).
- $\overline{Q_{std}}$ = average standard volume flow rate for the sample period, std. m³/min.
- $\overline{Q_a}$ = average actual volume flow rate for the sample period, m³/min.
- P_{av} = average ambient barometric pressure during the sample period, mm Hg.
- T_{av} = average ambient temperature during the sample period, K.

Inorganic Compendium Method IO-2.4 provides guidance on calculating sample volume corrected to EPA standard temperature and pressure.

11.2 Flow-Rate Calculations. Because flow control methods (and hence, calibration procedures) vary among different sampler models, the calculations necessary to determine the average actual flow rate during a sample run will also differ. The following general procedures are recommended for calculating the average ambient flow rate of the sampler. In this section, it is assumed that the samplers have been calibrated according to procedures outlined in Section 7.

[Note: Consistency in units is required. Adoption of uniform designations of K for temperature and mm Hg (or kPa) for pressure is recommended in all calculations.]

11.2.1 MFC Sampler.

11.2.1.1 The average actual flow rate for sample period is calculated by determining:

- The average of the initial and final manometer readings (\bar{P}_{ex}) [or the average flow recorder trace];
- The average ambient temperature (T_{av}); and
- The average ambient barometric pressure (P_{av}) during the sampling period and applying these values to the calibration relationship.

11.2.1.2 Each sampler's flow measurement system should be calibrated periodically, and the calibration should be described by a mathematical expression (e.g., a least-squares linear regression equation) that indicates the slope and intercept of the calibration relationship. Following the procedure in Section 7, this expression is in the form of:

$$\overline{Q_a} = \{[\overline{P_{ex}}(T_{av} + 30)/P_{av}]\}^{1/2} - b\} \{1/m\}$$

where:

- $\overline{Q_a}$ = the sampler's average actual flow rate for the sample period, m³/min.
- $\overline{P_{ex}}$ = average of initial and final sampler manometer readings, ($\bullet P_{ex_i} + \bullet P_{ex_f}$)/2, in. H₂O.
- T_{av} = average barometric pressure for the sample period, K ($K = \bullet C + 273$).
- P_{av} = average barometric pressure for the sample period, mm Hg.
- b = intercept of the sampler calibration relationship.
- m = slope of the sampler calibration relationship.

For the flow recorder,

$$\overline{Q_a} = \{[\overline{I}(T_{av} + 30)/P_{av}]\}^{1/2} - b\} \{1/m\}$$

where:

- \overline{I} = average flow recorder reading for the sample period.

11.2.1.3 The average actual flow rate is then corrected to EPA-standard conditions, calculated as:

$$\overline{Q_{std}} = \overline{Q_a}(P_{av}/P_{std})(T_{std}/T_{av})$$

where:

- $\overline{Q_{std}}$ = average sampler flow rate corrected to EPA-standard volume flow rate units, std. m³/min.
- $\overline{Q_a}$ = average actual sampler flow rate for the sample period, m³/min.
- P_{std} = standard barometric pressure, 760 mm Hg.
- T_{std} = standard temperature, 288 K.

11.2.2 VFC Sampler.

11.2.2.1 The average actual flow rate for the sample period is calculated by determining the ratio of the average absolute stagnation pressure of the average ambient barometric pressure ($\overline{P_I}/P_{av}$) and the ambient average temperature (T_{av}) for the sampler period.

11.2.2.2 Calculate the value of P_I in mm Hg:

$$\overline{P_I} = P_{av} - \bullet \overline{P_{stg}}$$

where:

- P_I = average absolute stagnation pressure for the sample period, mm Hg.
- P_{av} = average barometric pressure for the sample period, mm Hg.
- $\bullet \overline{P_{stg}}$ = average of initial and final relative stagnation pressure readings, mm Hg.

[Note: Be sure to convert a water manometer reading to mm Hg using the following equation before recording the reading on the data sheet:]

$$\text{mmHg} = 25.4 (\bullet H_2O/13.6)$$

11.2.2.3 Calculate and record the value of the average stagnation pressure ratio.

$$\text{Average stagnation pressure ratio} = (\overline{P_1}/P_{av})$$

11.2.2.4 Use the manufacturer's lookup table (or alternate calibration relationship; see Section 7) to determine Q_a from the average stagnation pressure ratio ($\overline{P_1}/P_{av}$) and T_{av} for the sample period. The value of $\overline{Q_a}$ is the average volumetric flow rate for the sampler period.

11.2.2.5 The average actual flow rate is then corrected to EPA-standard conditions using the following equation:

$$\overline{Q_{std}} = \overline{Q_a} (P_{av}/P_{std}) (T_{std}/T_{av})$$

where:

$\overline{Q_{std}}$ = average sampler flow rate corrected to EPA-standard volume flow rate units, std. m³/min.

$\overline{Q_a}$ = average actual sampler flow rate for the sample period, m³/min.

P_{std} = standard barometric pressure, 760 mm Hg.

T_{std} = standard temperature, 298 K.

11.3 The total standard volume of air sampled is calculated by the following equation:

$$V_{std} = (\overline{Q_{std}})(t)$$

where:

V_{std} = total volume of air sampled in standard volume units, std m³.

$\overline{Q_{std}}$ = average sampler flow rate corrected to EPA-standard conditions, std m³/min.

t = total elapsed sampling time, min.

11.4 Percent Difference

11.4.1 After each sampling period, calculate the percentage difference between Q_a and the design flow rate (1.13 m³/min) using the following formula:

$$\% \text{ Difference} = 100 \frac{Q_a - 1.13}{1.13}$$

Record this value on a control chart for the field validation of the sampler's actual volumetric flow rate as is shown in Figure 14.

11.4.2 The following criteria should be used as the basis for determining a sample's validity:

- Decreases in flow rate during sampling (due to mechanical problems) of more than 10% from the initial set point cause sample invalidation. A sample flow rate may also fluctuate due to heavy filter loading. If a high concentration is suspected, the operator should indicate it on the field data sheet. The laboratory supervisor will make the final decision regarding the sample's validity.
- Changes in flow-rate calibration of more than 10%, as determined by a field QC flow-rate check, will invalidate all samples collected back to the last calibration or valid flow check.

12. Records

12.1 MFC Sampler

Record the following parameters on the MFC Sampler Field Data Sheet (see Figure 14):

- Final Pex.
- Elapsed time of the sampling period, min.
- Average record response, arbitrary units.
- T_{av} for the run day K ($K = ^\circ C + 273$).
- P_{av} for the run day, mm Hg.

12.2 VFC Sampler

Record the following parameters on the VFC Sampler Field Data Sheet (see Figure 15):

- Site location.
- Sample date.
- Filter ID number.
- Sampler model and S/N
- Operator's initials.
- Initial Relative Stagnation Pressure (Pstg).
- Elapsed time of the sampling period, min.
- T_{av} for the run day T_{av} , $^\circ C$ and K.
- P_{av} for the run day P_{av} , mm Hg.
- Pstg, mm Hg.
- Relative Stagnation Pressure.
- Absolute Stagnation Pressure.
- Q_a value (from chart generated in Section 7.5.4.).

12.3 T_{av} and P_{av} readings may be recorded or estimated on site or may be obtained from a nearby U.S. National Weather Service Forecast Office or airport weather station. Barometric pressure readings obtained from remote sources must be at station pressure (not corrected to sea level); they may have to be corrected for differences between elevation of the monitoring site and that of the airport. If T_{av} and P_{av} readings are not available, seasonal average temperature (T_s) and barometric pressure (P_s) may be substituted for T_{av} and P_{av} , respectively. Care must be taken, however, that the actual conditions at the site can be reasonably represented by such averages. Therefore, seasonal values should represent actual values within $20^\circ C$ and 40 mm Hg.

12.4 Observe conditions around the monitoring site; note any activities that may affect filter particle loading (paving, mowing, fire) and record this information on the VFC Sampler Field Data Sheet. Document any factors that may cause a sample's invalidation on the sample data sheet. Forward the data sheet and the filter to the laboratory supervisor, who will make the final decision regarding the sample's validity.

12.5 Record the percentage difference between Q_a and the design flow rate on Figure 16.

12.6 Recordkeeping is a critical part of the QA program. Careful documentation of sampling data will salvage samples that may otherwise be lost. The sheer repetition of recording data may result in errors;

however, this cross-referencing between data sheets, log books, and (for those samplers so equipped) the continuous-flow-recorder charts will allow the operator to pinpoint discrepancies that may result in a sample's invalidation.

[Note: The use of log books at monitoring sites is highly encouraged. The following information should be recorded on the Sampler Field Data Sheet (SFDS), sampler recorder chart (RC), in the site log book (LB), and on the flow-rate control chart (CC).]

12.6.1 The following information should be recorded by the operator who starts the sample. (The designation in parentheses indicates where the data must be inscribed):

- Site designation and locations (SFDS)(RC)(LB). This information should be recorded in the log book only once, at the initiation of a monitoring program.
- Sampler model and S/N (SFDS)(RC)(LB). This information needs to be recorded in the log book only at the commencement of monitoring, unless there is more than one sampler or a new sampler has been deployed.
- Filter ID number (SFDS)(RC)(LB).
- Sample date (SFDS)(RC)(LB).
- Initial Pex for MFC or initial • Pstg for VFC (SFDS)(LB).
- Unusual conditions that may affect the results (e.g., subjective evaluation of pollution that day, construction activity, weather conditions) (SFDS)(LB).
- Operator's initials (SFDS).
- Signature (LB).

12.6.2 The following information should be recorded by the operator who removes the samples.

- Elapsed time of the sample run (SFDS)(RC)(LB).
- Final • Pex [or mean I] for MFC or final • Pstg, \overline{PI} , and \overline{PI}/P_{av} for VFC (DS)(LB)[RC].
- The calculated standard average flow rate (Q_{std}) in m^3/min (SFDS)(LB).
- The percentage difference between the actual and design flow rates (CC).
- Average ambient temperature and barometric pressure on the sample run day (SFDS)(LB).
- Seasonal average temperature and pressure, if needed (SFDS/LB). This information needs to be recorded in the logbook once, at the change of each season.
- Existing conditions that may affect the results (SFDS)(LB).
- Explanations for voided or questionable samples (SFDS)(LB).
- Operator's initials (SFDS).
- Signature (LB).

13. Field QC Procedure

For HV samplers, a field-calibration check of the operational flow rate is recommended at least once per month. The purpose of this check is to track the sampler's calibration stability. A control chart (e.g., Figure 14) that contains the percentage difference between a sampler's indicated and measured flow rates should be maintained. This chart is a quick reference of instrument flow-rate drift problems and is useful for tracking the performance of the sampler. Either the sampler log book or a data sheet must be used to document flow-check information. This information includes, but is not limited to, instrument and transfer standard model and serial numbers, ambient temperature and pressure conditions, and collected flow-check data.

In this section, the following is assumed:

- The flow rate through sampler that is equipped with a mass-flow controller is indicated by the exit orifice plenum pressure. This pressure is measured with a manometer [or a flow recorder].
- The flow rate through a sampler that is equipped with a volumetric flow controller is indicated by the stagnation pressure. This pressure is measured with a manometer.
- The acceptable flow-rate fluctuation range is 10% of the design flow rate.
- The transfer standard will be an orifice device equipped with a water or oil manometer.
- The orifice transfer standard's calibration relationship is in terms of the actual volumetric flow rate (Q_a).

13.1 QC Flow-Check Procedure--MFC Sampler. The indicated flow rate [Q_a (sampler)] for MFC samplers is calculated by determining:

- The manometer reading of the exit orifice plenum pressure [or the flow recorder reading],
- The ambient temperature (T_a), and
- The barometric pressure (P_a) during the flow check.

These values are then applied to the sampler's calibration relationship. The 4" pressure (flow) recorders of the type often supplied with high-volume PM_{10} samplers are generally not sufficiently accurate and are not recommended for quantitative sampler pressure or flow measurements. The flow recorder may be connected in parallel with the manometer or other pressure measuring device, using a tee or "Y" tubing connector. An alternate QC flow-check procedure may be presented in the manufacturer's instruction manual. The manual should be reviewed and the various methods evaluated. Inhouse equipment and procedural simplicity should be considered in determining which method to use.

[Note: Do not attempt to conduct a flow check of samplers under windy conditions. Short-term wind velocity fluctuations will produce variable pressure readings by the orifice transfer standard's manometer. The flow check will be less precise because of the pressure variations.]

13.1.1 Collect the following equipment and transport it to the monitoring station:

[Note: An independent person should perform the QC flow check, with an outside observer present.]

- A water, oil, or digital manometer with a 0-200 mm (0-8") range and a minimum scale division of 1 mm (0.1") for measuring the sampler's exit orifice plenum pressure. This manometer should be the same as is used routinely for sampler flow rate measurements.
- An orifice transfer standard and its calibration relationship (different from initial orifice standard).
- An associated water or oil manometer with a 0- to 400-mm (0- to 16") range and a minimum scale division of 1 mm (0.1") for measuring the orifice transfer standard.
- A thermometer capable of accurately measuring temperature 0-50°C (273-323 K) to the nearest $\pm 1^\circ\text{C}$ and referenced to an NIST or ASTM thermometer within $\pm 2^\circ\text{C}$ at least annually.
- A portable aneroid barometer (e.g., a climber's or engineer's altimeter) capable of accurately measuring ambient pressure 500-800 mm Hg (66-106 kPa) to the nearest millimeter Hg and referenced within ± 5 mm Hg of a barometer of known accuracy at least annually.
- The sampler's calibration information.
- Spare recorder charts and a clean flow-check filter.
- MFC Sampler Flow-Check Data Sheet or site log book.

13.1.2 Record the site location, sampler S/N, and date on the back of a clean chart and install it in the flow recorder. While installing the chart, do not bend the pen arm beyond its limits of travel. Raise the pen head by pushing on the very top of the pen arm (or by using the pen lift) and simultaneously insert the chart.

13.1.3 Lower the pen arm and tap the recorder face lightly to make certain that the pen can move freely.

13.1.4 Using a coin or slotted screwdriver, advance the chart and check to see that the pen head rests on zero (i.e., that smallest diameter circle). If necessary, adjust the zeroset screw while gently tapping on the side of the recorder. A quarter turn of the set screw usually results in large offsets; adjust the set screw carefully.

13.1.5 Set up the flow-check system as previously illustrated in Figure 10. MFC samplers are normally flow-checked with a filter in line (i.e., between the orifice transfer standard and the motor). Install a clean filter in the sampler. Place the filter directly upon the sampler's filter screen. Do not use a filter cassette. A flow-check filter should never be used for subsequent sampling because particles larger than $10 \mu\text{m}$ can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both a flow check and subsequent sampling.

13.1.6 Install the orifice transfer standard and its faceplate on the sampler. Do not restrict the flow rate through the orifice (i.e., by using fixed resistance plates or closing the variable-resistance valve).

Caution: Tighten the faceplate nuts on alternate corners first to eliminate leaks and to ensure even tightening. The nuts should be hand-tightened; too much compression can damage the sealing gasket. Make sure the orifice transfer standard gasket is in place and the orifice transfer standard is not cross-threaded on the faceplate.

13.1.7 Connect the orifice manometer to the pressure port of the orifice transfer standard and the sampler manometer to the sampler's exit orifice plenum. Inspect the manometers' connecting tubings for crimps and cracks. Open the manometer valves and blow gently through the tubings. Watch for the free flow of fluid. Adjust the manometers' scales so that their zero lines are at the bottom of the meniscuses. Make sure that the connecting tubing snugly fits the manometer and the pressure port.

13.1.8 Turn on the sampler and allow it to warm up to operating temperature (3-5 min).

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom for air flow and for the manometer tubing.]

13.1.9 Read and record the following parameters on the MFC Sampler Flow-Check Data Sheet:

- Sampler location and date.
- Sampler model and S/N.
- Ambient temperature (T_a), $^{\circ}\text{C}$ and K .
- Ambient barometric pressure (P_a), mm Hg .
- Unusual weather conditions.
- Orifice transfer standard S/N and calibration relationship.
- Operator's signature.

13.1.10 Observe the $\bullet \text{H}_2\text{O}$ across the orifice by reading the manometer deflection. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet (see Figure 11).

13.1.11 Measure the exit orifice plenum pressure ($\bullet P_{\text{ex}}$) by reading the manometer deflection. Record the manometer deflection on the MFC Sampler Flow-Check Data Sheet.

13.1.12 Using a coin or small screwdriver, advance the recorder chart to read the sampler's corresponding response (I) and record on the data sheet. A gentle tap on the recorder face is often necessary to ensure that the pen is not sticking to the chart.

13.1.13 Turn off the sampler and remove the orifice transfer standard, but not the filter. Turn on the sampler and repeat Section 13.1.11 [or Section 13.1.12] to check the flow rate under normal operating conditions. Turn off the sampler and remove the filter.

13.1.14 Calculate and record $Q_a(\text{orifice})$ at actual conditions using the following equation:

$$Q_a(\text{orifice}) = \{[(\bullet \text{ H}_2\text{O})(T_a/P_a)]^{1/2} - b\} \{1/m\}$$

where:

$Q_a(\text{orifice})$ = actual volumetric flow rate as indicated by the orifice transfer standard, m^3/min

- H_2O = pressure drop across the orifice, in. H_2O .
- T_a = ambient temperature, K.
- P_a = ambient barometric pressure, mm Hg.
- b = intercept of the orifice calibration relationship.
- m = slope of the orifice calibration relationship.

13.1.15 Calculate and record the corresponding sampler flow rate at actual conditions using the following equation:

$$Q_a(\text{sampler}) = \{\bullet \text{ Pex } (T_a + 30)/P_a\}^{1/2} - b\} \{1/m\}$$

or use the following if a flow recorder is being used to measure the exit orifice plenum pressure:

$$Q_a(\text{sampler}) = \{1(T_a + 30)/P_a\}^{1/2} - b\} \{1/m\}$$

where:

$Q_a(\text{sampler})$ = sampler flow rate, actual m^3/min .

- Pex = exit orifice plenum pressure, in. H_2O .
- T_a = ambient temperature during the flow check, K ($K = \bullet C + 273$).
- P_a = ambient barometric pressure during the flow check, mm Hg.
- b = intercept of the MFC sampler calibration relationship.
- m = slope of the MFC sampler calibration relationship.

[Note: If charts with linear-function scales are used, substitute $(I)^*$ for I .]

13.1.16 Using this information and the formulas provided on the MFC Sampler Flow-Check Data Sheet, calculate the QC check percentage differences.

$$\text{QC} \bullet \text{ check \% difference} \bullet \frac{[Q_a(\text{sampler}) \bullet Q_a(\text{orifice})]}{Q_a(\text{orifice})} [100]$$

where:

$Q_a(\text{sampler})$ is measured with the orifice transfer standard being installed.

Record this value on the MFC Sampler Flow-Check Data Sheet and plot on the QC control chart. If the sampler flow rate is within 93-107% ($\pm 7\%$ difference) of the calculated $Q_a(\text{orifice})$ flow rate (in actual volumetric units), the sampler calibration is acceptable. If these limits are exceeded, investigate and correct any malfunction. Recalibrate the sampler before sampling is resumed. Differences exceeding $\pm 10\%$ may result in the invalidation of all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the orifice transfer standard's calibration and all calculations.

13.1.17 Calculate the corrected sampler flow rate, $Q_a(\text{corr. sampler})$, using the following equation:

$$Q_a(\text{corr. sampler}) = [Q_a(\text{sampler})] \frac{[(100 \cdot \% \text{ difference})]}{100}$$

where:

$Q_a(\text{sampler})$ is measured without the orifice transfer standard being installed and where the QC-check percentage difference was obtained from the equation above.

[Note: Take care to use the correct sign (i.e., positive or negative) for the percent difference.]

13.1.18 Calculate and record on the MFC Sampler Flow-Check Data Sheet the percentage difference between the inlet's design flow rate and the corrected sampler flow rate as:

$$\text{Design flow rate \% difference} = \frac{[Q_a(\text{corr. sampler}) \cdot 1.13]}{1.13} [100]$$

[Note: The author assumes in this section that the inlet is designed to operate at a flow rate of 1.13 actual m^3/min . If the design flow rate percentage difference is less than or equal to $\pm 7\%$, the sampler calibration is acceptable. If the difference is greater than $\pm 7\%$, investigate potential error sources and correct any malfunction. Recalibrate the sampler before sampling is resumed. Differences exceeding $\pm 10\%$ may invalidate all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calculations.]

[Note: Deviations from the design flow rate may be caused in part by deviations in the site temperature and pressure from the seasonal average conditions. Recalculate the optimum set-point flow rate (SFR) according to Section 7.4.4 to determine if the flow controller should be adjusted.]

13.1.19 Set up the sampler for the next sampling period according to the operating procedure in Section 9.4.

13.2 QC Flow-Check Procedure--VFC Sampler

The indicated flow rate ($Q_a(\text{sampler})$) for VFC samplers is calculated by determining:

- The relative stagnation pressure (P_{stg}),
- The ambient temperature (T_a), and
- The barometric pressure (P_a) during the flow check.

These values are then applied to the sampler's calibration relationship. An alternative QC flow-check procedure may be presented in the manufacturer's instruction manual. The manual should be reviewed and the various methods evaluated. Inhouse equipment and procedural simplicity should be considered in determining which method to use.

[Note: Do not attempt to conduct a flow check of samplers under windy conditions. Short-term wind velocity fluctuations will provide variable pressure readings by the orifice transfer standard's manometer.]

The flow check will be less precise because of the pressure variations.

13.2.1 Collect the following equipment and transport it to the monitoring station:

- An orifice transfer standard and its calibration relationship in actual volumetric flow units (Qa).
- An associated oil, water, or digital manometer, with a 0-400 mm (0-16") range and minimum scale divisions of 1 mm (0.1").
- An oil, water, or digital manometer, with a 0-400 mm (0-16") range and minimum scale divisions of 1 mm (0.1") or other pressure measurement device for measurement of the sampler stagnation pressure. Ideally, this manometer (or other pressure measurement device) should be associated with the sampler.

[Note: Manometers used for QC flow-checks may be subject to damage or malfunction and thus should be checked frequently.]

- A thermometer capable of accurately measuring temperature from 0• -50• C (273-323 K) to the nearest $\pm 1\text{•C}$ and referenced to an NIST or ASTM thermometer within 2•C at least annually. To calculate the orifice flow rates, convert •C to K.
- A portable aneroid barometer (e.g., a climber or engineer's altimeter) capable of accurately measuring ambient barometric pressure over the range of 500-800 mm Hg to the nearest millimeter Hg and referenced within 5 mm Hg of a barometer of known accuracy at least annually.
- The sampler's calibration relationship (i.e., lookup table or alternative calibration relationship).
- A clean flow-check filter loaded into a filter cassette.
- A VFC Sampler Flow-Check Data Sheet (see Figure 13) or a site log book.

13.2.2 Set up the flow-check system as previously illustrated in Figure 12. VFC samplers are normally flow-checked with a loaded filter cassette in line (i.e., between the orifice transfer standard and the motor). The orifice transfer standard should be installed without fixed resistance plates or with the adjustable resistance value fully open. A flow-check filter should never be used for subsequent sampling because particles larger than 10 • m can be collected on the filter while the inlet is raised. The sample mass will be biased as a result of using a filter for both a flow check and subsequent sampling.

Caution: Tighten the faceplate nuts on alternate corners first to eliminate leaks and to ensure even tightening. The fittings should be hand-tightened; too much compressing can damage the sealing gasket. Make sure the orifice gasket is in place and the orifice transfer standard is not cross-threaded on the faceplate.

13.2.3 Turn on the sampler and allow the sampler to warm up to operating temperature (3-5 min).

[Note: The sampler inlet may be partially lowered over the orifice transfer standard to act as a draft shield (if a shield is not otherwise provided). Use a block to provide at least 2" of clearance at the bottom for air flow and for the manometer tubing.]

13.2.4 Read and record the following parameters on the VFC Sampler Flow-Check Data Sheet (see Figure 13):

- Sampler location and date.
- Sampler S/N and model.
- Ambient temperature (Ta), •C and K.
- Ambient barometric pressure (Pa), mm Hg.
- Unusual weather conditions.
- Orifice transfer standard S/N and calibration relationship.
- Operator's signature.

13.2.5 Inspect the manometers for crimps or cracks in the connecting tubing. Open the valves and blow gently through the tubing, watching for the free flow of the fluid. Adjust the manometers' sliding scales so that the zero lines are at the bottom of the menisci.

13.2.6 Connect the orifice manometer to the orifice transfer standard and the sampler manometer to the sampler stagnation pressure port located on the side of the sampler base. Ensure that one side of each manometer is open to atmospheric pressure. Be sure that the connecting tubing snugly fits the pressure ports and the manometers.

13.2.7 Read the pressure drop as indicated by the orifice manometer (\bullet H₂O) and record the value on the VFC Sampler Flow-Check Data Sheet. Read the stagnation pressure drop and record it as \bullet Pstg (mm Hg) on the data sheet.

[Note: Be sure to convert the manometer reading to mm Hg using the following equation before recording the reading on the data sheet.]

$$\text{mm Hg} = 25.4(\text{in. H}_2\text{O}/13.6)$$

13.2.8 Turn off the sampler and remove the orifice transfer standard.

13.2.9 With only a loaded filter cassette in line, turn on the sampler and allow it to warm up to operating temperature.

13.2.10 Read and record the stagnation pressure drop (\bullet Pstg) for the normal operating flow rate. Turn off the sampler. Replace the vacuum cap on the stagnation pressure port.

13.2.11 Calculate and record Qa(orifice) flow rate for the flow-check point, as in the equation, reproduced below:

$$Qa(\text{orifice}) = \{[(\bullet \text{ H}_2\text{O})(Ta/Pa)]^{1/2} - b\} [l/m]$$

where:

Qa(orifice) = actual volumetric flow rate as indicated by the transfer standard orifice, m³/min.

\bullet H₂O = pressure drop across the orifice, in. H₂O.

Ta = ambient temperature, K (K = \bullet C + 273).

Pa = ambient barometric pressure, mm Hg.

b = intercept of the orifice calibration relationship.

m = slope of the orifice calibration relationship.

13.2.12 Calculate and record the value of Pl (mm Hg) for the measurements, with and without the orifice installed, according to the following equation:

$$Pl = [Pa - \bullet \text{ Pstg}]$$

where:

Pl = stagnation pressure, mm Hg.

Pa = ambient barometric pressure, mm Hg.

\bullet Pstg = stagnation pressure drop, mm Hg.

13.2.13 Calculate and record the stagnation pressure ratio for the measurements, with and without the orifice installed, according to the following equation:

$$\text{Stagnation pressure ratio} = Pl/Pa$$

where:

Pl = stagnation pressure, mm Hg.

Pa = ambient barometric pressure, mm Hg.

13.2.14 Refer to the instrument manufacturer's lookup table (or alternative calibration relationship as described in Section 7.5.4) and determine the Qa(sampler) flow rates (m³/min) for the measurements with

and without the orifice installed as indicated for the ratio of P_i/P_a and ambient temperature in °C. Record these values on the VFC sampler flow check data sheet.

13.2.15 Using $Q_a(\text{orifice})$ and $Q_a(\text{sampler})$ for the measurements with the orifice installed, calculate the QC-check percentage difference as:

$$\text{QC-check \% difference} = \frac{[Q_a(\text{sampler}) \cdot Q_a(\text{orifice})]}{Q_a(\text{orifice})} [100]$$

Record this value on the VFC Sampler Flow-Check Data Sheet and plot it on the control chart for QC flow checks. If the QC-check percentage difference is less than or equal to $\pm 7\%$, the sampler calibration is acceptable. Those differences exceeding $\pm 7\%$ will require recalibration. Differences exceeding $\pm 10\%$ may invalidate all data collected subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calibrations.

13.2.16 Using this percentage difference and $Q_a(\text{sampler})$ from the measurements without the orifice installed (i.e., for the normal operating flow rate), calculate the corrected sampler flow rate as:

$$Q_a(\text{corr. sampler}) = [Q_a(\text{sampler})] \frac{[(100 \cdot \% \text{ difference})]}{100}$$

Record $Q_a(\text{corr. sampler})$ on the VFC Sampler Flow-Check Data Sheet.

13.2.17 Determine the design flow rate percentage difference between the PM_{10} sampler inlet design flow rate (e.g., $1.13 \text{ m}^3/\text{min}$) and $Q_a(\text{corr. sampler})$ as:

$$\text{QC-check \% difference} = \frac{[Q_a(\text{sampler}) \cdot Q_a(\text{orifice})]}{Q_a(\text{orifice})} [100]$$

Record this design flow rate percentage difference on the VFC Sampler Flow-Check Data Sheet and plot it on the control chart for the field validation of flow rates. When plotting this value, use a different symbol than is normally used for plotting values that are obtained during sampling periods. If the design flow rate percentage difference is less than or equal to $\pm 7\%$, the sampler calibration is acceptable. Those differences exceeding $\pm 7\%$ will require recalibration. Differences exceeding $\pm 10\%$ may invalidate all data obtained subsequent to the last calibration or valid flow check. Before invalidating any data, double-check the sampler's calibration, the orifice transfer standard's certification, and all calculations.

14. Maintenance

Maintenance is defined as a program of positive actions aimed toward preventing failure of monitoring and analytical systems. The overall objective of a routine preventive maintenance program is to increase measurement system reliability and provide more complete data acquisition. The general maintenance procedures for HV samplers are outlined in this section. For more complete information on a particular sampler or on laboratory equipment maintenance, refer to the manufacturer's instruction manual for the individual instrument. Maintenance activities for the HV sampler are summarized in Table 4. Records should be maintained for the maintenance schedule of each HV sampler. Files should reflect the history of maintenance, including all replacement parts, suppliers, costs, expenditures, and in inventory of on-hand spare equipment for each sampler. Check sheets should be used to record preventive and/or corrective maintenance activities and the subsequent sampler calibration curve.

14.1 Maintenance Procedures

The HV sampler is comprised of two basic components: the inlet and the flow control system. Because of the differences between sampler models, refer to the manufacturer's instruction manual for specific maintenance guidelines and necessary supplies.

14.2 Recommended Maintenance Schedules

14.2.1 MFC Base. The MFC base is equipped with the following items:

14.2.1.1 Connecting tubing and power lines, which must be checked for crimps, cracks, or obstructions on sample recovery days. Fittings should be inspected periodically for cross-threading and tightness.

14.2.1.2 A filter screen, which should be inspected on sample recovery days for any impacted deposits.

14.2.1.3 Filter cassette gaskets, which need to be inspected each time a cassette is loaded. A worn cassette gasket is characterized on exposed filters by a gradual blending of the boundary between the collected particulate and the filter border.

14.2.1.4 Motor and housing gaskets, which should be checked at 3-month intervals and replaced as necessary.

14.2.1.5 Blower motor brushes, which should be replaced before they become worn to the point that damage may occur. Although motor brushes usually require replacement after 600-1,000 hours of operation, the optimum replacement interval must be determined by experience. A pumice stone can be used against the motor's contacts to ensure high conductivity. Change the brushes according to manufacturer's instructions and perform the operator's field-calibration check as presented in Section 13. If the sampler's indicated flow rate exceeds the manufacturer-specified design-flow-rate range, adjust the sampler before the next run day.

To achieve the best performance, new brushes should be properly seated on the motor's commutator before full voltage is applied to them. After the brushes have been changed, operate the sampler at 50-75% of normal line voltage for approximately 30 min. The motor should return to full performance after an additional 30-45 min at normal line voltage.

[Note: The motors that are used for HV samplers are higher-current versions of the motors that have been used for HV total suspended particulate samplers. The brushes for the two types of motors are different. Make sure that the correct replacement brushes are used for the maintenance of HV samplers. If a motor needs to be replaced, be sure to use the higher-current versions that are needed for HV sampling. When lower-current motors are installed in HV samplers, the flow rate has been found to vary with changes in the line voltage.]

14.2.1.6 A flow controller should be replaced if the flow recorder indicates no flow, low flow, excessive flow, or erratic flow. Minor adjustments can be made to alter sampling flow rates; however, the controller generally cannot be repaired in the field.

[Note: A flow recorder requires very little maintenance, but does deteriorate with age. Difficulty in zeroing the recorder and/or significant differences (i.e., greater than 0.3 m³/min) in average flow rates obtained from consecutive sampling periods usually indicate a faulty recorder. The recorder pens should be replaced every 30 recording days. In dry climates, a more frequent replacement schedule may be required.]

14.2.2 VFC Base. The VFC base is equipped with the following items:

14.2.2.1 Power lines, which must be checked for crimps or cracks on sample recovery days. Fittings should be inspected periodically for cross-threading and tightness.

14.2.2.2 A filter screen at the throat of the choked-flow venturi, which should be inspected on sample recovery days for any impacted deposits.

14.2.2.3 Filter cassette gaskets, which should be checked each time a filter is installed. A worn cassette gasket is characterized on exposed filters by a gradual blending of the boundary between the collected particulates and the filter border.

14.2.2.4 Motor and housing gaskets, which should be checked at 3-month intervals and replaced as necessary.

14.2.2.5 Blower motor brushes, which should be replaced before they become worn to the point that damage may occur. Although motor brushes usually require replacement after 600-1,000 hours of operation, the optimum replacement interval must be determined by experience. A pumice stone can be used against the motor's contacts to ensure high conductivity. Change the brushes according to manufacturer's instructions, and perform the operator's field-calibration check as presented in Section 13. If the sampler's indicated flow rate exceeds the manufacturer-specified design flow-rate range, recalibrate the sampler before the next run day.

To achieve the best performance, new brushes should be seated properly on the motor's commutator before full voltage is applied to them. After the brushes have been changed, operate the sampler at 50-75% of normal line voltage for approximately 30 min. The motor should return to full performance after an additional 30-45 min at normal line voltage.

Caution: Motors that are used for HV PM₁₀ samplers are higher-current versions of the motors that have been used for HV total suspended particulate samplers. The brushes for the two types of motor are different. Make sure that the correct replacement brushes are used for the maintenance of HV PM₁₀ samplers.

14.2.2.6 If a motor needs to be replaced, be sure to use the higher-current versions that are needed for HV PM₁₀ sampling. When lower-current motors are installed in HV PM₁₀ samplers, the flow rate has been found to vary with changes in the line voltage.

14.3 Refurbishment of HV Samplers

If operated in the field for extended periods, HV PM₁₀ samplers may require major repairs or complete refurbishment. If so, refer to the manufacturer's instrument manual before work is undertaken. A sampler that has undergone major repairs or refurbishment must be leak-checked and calibrated prior to sample collection.

15. REFERENCES

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TABLE 1. EXAMPLE OF BASIC CHARACTERISTICS OF SOME COMMON FILTER MATERIAL

<p>QUARTZ FIBER FILTER (Glass Spun with Organic Binder)</p>	
!	<p>Whatman QMA Filter</p> <p>! Maximum temperature of up to 540°C</p> <p>! High Collection Efficiency</p> <p>! Non-hygroscopic</p> <p>! Good for Corrosive Atmospheres</p> <p>! Fragile</p> <p>! Lowest background metals content</p>
<p>CELLULOSE FIBER FILTER (Cellulose Pulp)</p>	
!	<p>Whatman # 41/MSA "s"</p> <p>! Low Ash</p> <p>! Maximum Temperature of 150°C</p> <p>! High Affinity for Water</p> <p>! Enhanced Artifact Formation for SO₂ and NO₂</p> <p>! Good for X-Ray/Neutron Activation Analysis</p> <p>! Low Metal Content</p>
<p>MEMBRANE FILTER (Dry Gel of Cellulose Esters)</p>	
!	<p>Whatman #41</p> <p>! Fragile, Therefore Requires Support Pad</p> <p>! High Pressure Drop</p> <p>! Low Residue when Ashed</p>

TABLE 2. EXAMPLE OF SUMMARY OF USEFUL FILTER PROPERTIES

Filter and Filter Composition	Density mg/cm ²	pH	Filter Efficiency %
Teflon® (Membrane) (CF ₂) _n (2µm Pore Size)	0.5	Neutral	99.95
Cellulose (Whatman 41) (C ₆ H ₁₀ O ₅) _n	8.7	Neutral (Reacts with HNO ₃)	58% at 0.3 µm
Glass Fiber (Whatman GF/C)	5.16	Basic pH - 9	99.0
"Quartz" Gelman Microquartz	6.51	pH - 7	98.5
Polycarbonate (Nuclepore) C ₁₅ H ₁₄ + CO ₃ (0.3µm Pore Size)	0.8	Neutral	93.9
Cellulose Acetate/Nitrate Millipore (C ₉ H ₁₃ O ₇) _n (1.21 µm Pore Size)	5.0	Neutral (Reacts with HNO ₃)	99.6

TABLE 3. EXAMPLE OF MINIMUM SAMPLER SITING CRITERIA

Scale	Height above ground, meters	Distance from supporting structure, meters		Other spacing criteria
		Vertical	Horizontal ^a	
Micro	2 to 7	> 2	> 2	<ol style="list-style-type: none"> Should be > 20 meters from trees. Distance from sampler to obstacle, such buildings, must be twice the height and the obstacle protrudes above the sampler. Must have unrestricted airflow 270 degrees around the sampler inlet. No furnace or incineration flues should be nearby.^b Spacing from roads varies with traffic (see 40 CFR 58, Appendix E). Sampler inlet is at least 2 m but not greater than 4 m from any collocated PM₁₀ sampler. (See 40 CFR 58, Appendix E.)
Middle, neighborhood, urban, and regional scale	2 to 15	> 2	> 2	

^aWhen inlet is located on rooftop, this separation distance is in reference to walls, parapets, or penthouses located on the roof.

^bDistance depends on the height of furnace or incineration flues, type of fuel or waste burned, and quality of fuel (sulfur, ash, or lead content). This is to avoid undue influences from minor pollutant sources.

TABLE 4. EXAMPLE OF ROUTINE MAINTENANCE ACTIVITIES
FOR SAMPLERS

Equipment	Frequency and/or method	Acceptance limits	Action if requirements are not met
Sampler inlet	Dismantle and clean at manufacturer-specified intervals	No obvious particulate deposits or damage	Clean, replace damaged equipment before sampling
Sampler base			
Power lines	Check for crimps or cracks	No obvious damage	Replace as necessary
Filter screen and throat	Visually check on sample-recovery days	No obvious deposits; clean with wire brush	Clean
Gaskets	At 3-mo intervals, inspect all gaskets in the sampler	No leaks; no compression damage evident	Replace as necessary
Brushes	Replace after 600-1,000 h of operation	Stable flow rate	Replace as necessary
Motor	Replace if needed	Correct model must be used	Obtain correct model
Flow controller	Check when flowrate changes are evident	Stable flow rate throughout sample run	Replace or repair if possible
Recording device	Inspection with experiencing difficulty in zeroing, or when large changes in flow rates occur	Recorder stays zeroed; chart advances; pen inks	Replace or repair if possible
Tubing, fittings	Visually inspect on sample-recovery days	No crimps, cracks, or obstructions; no crossthreading	Replace as necessary.

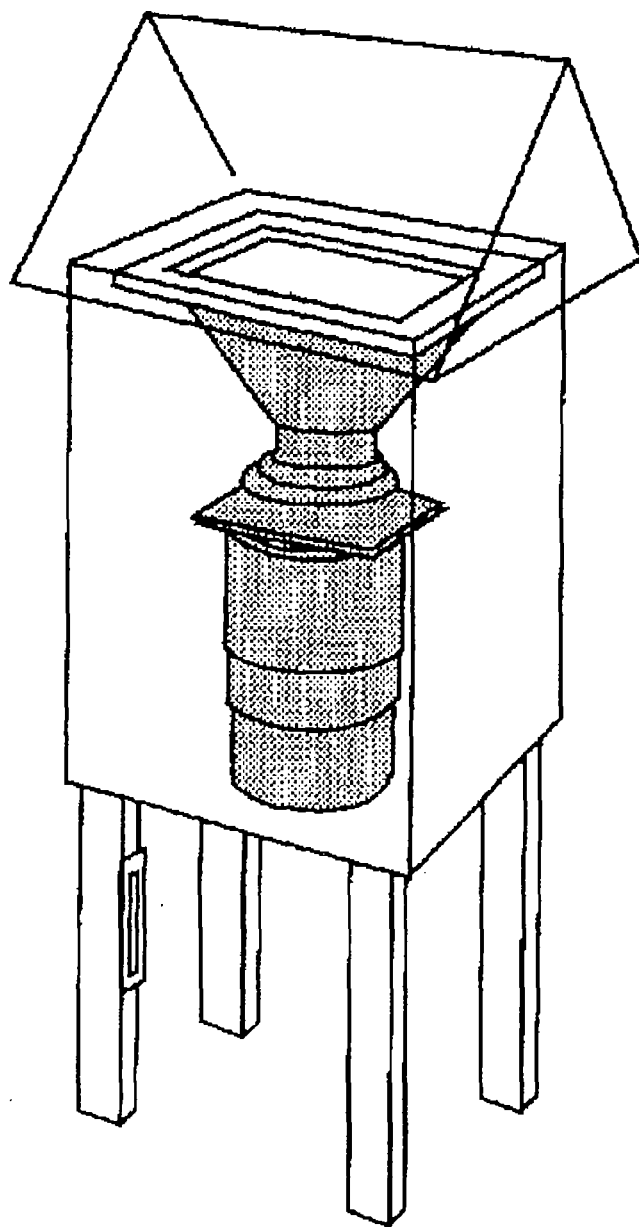


Figure 1. High-volume sampler with shelter.

Hi Volume Sampler in Shelter

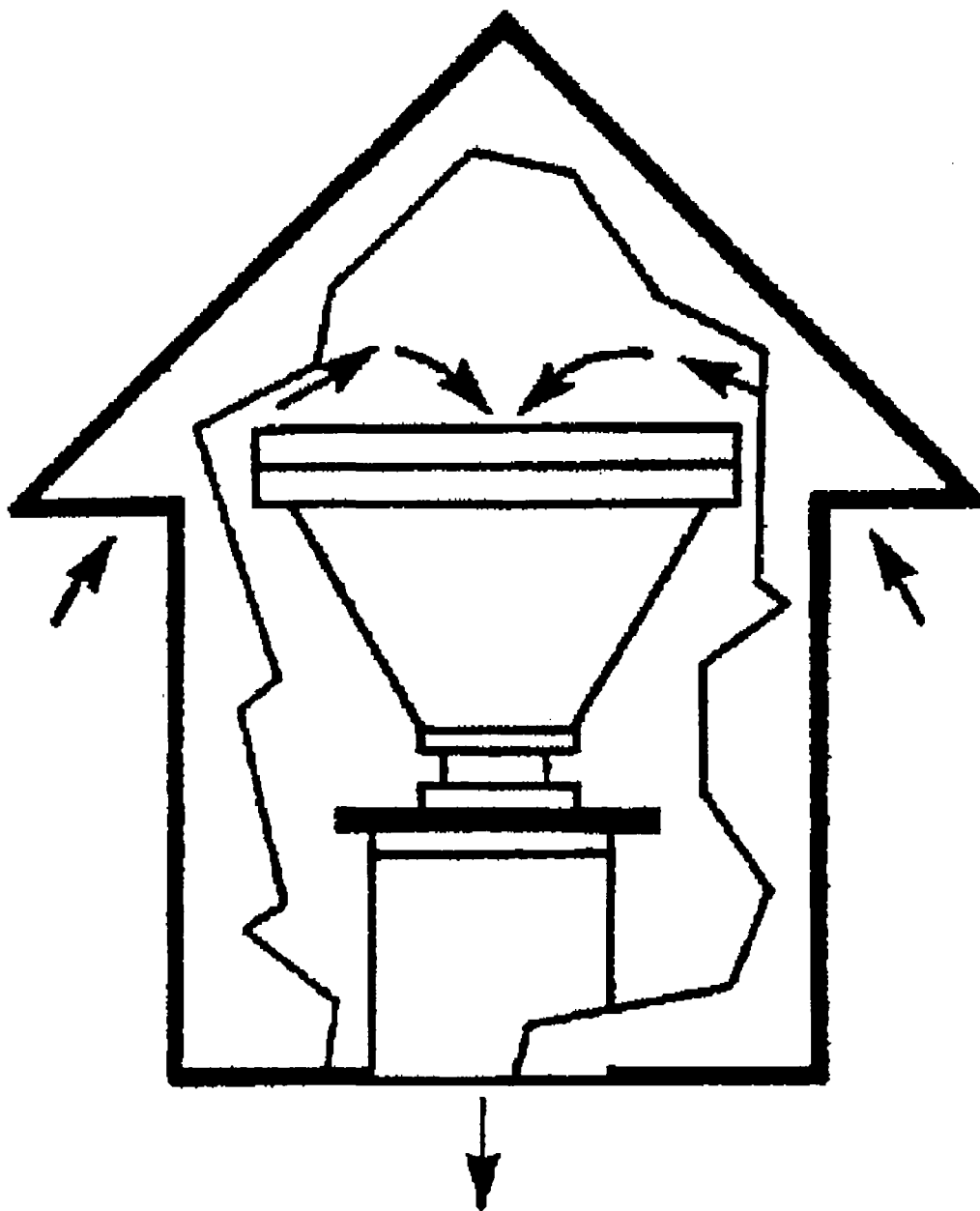


Figure 2. Inlet to EPA approved high volume sampler.

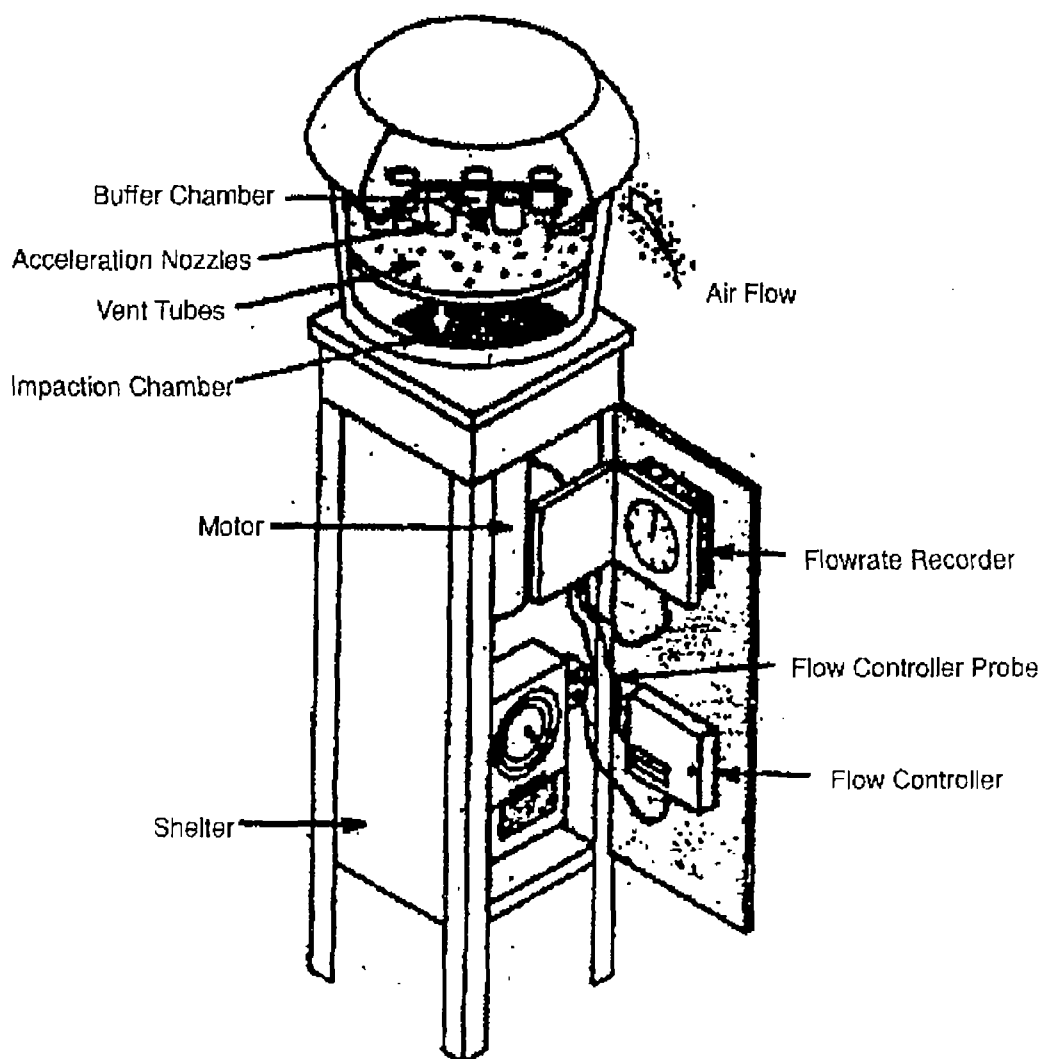


Figure 3. High-volume sampler with mass flow controller and impactor design size select inlet.

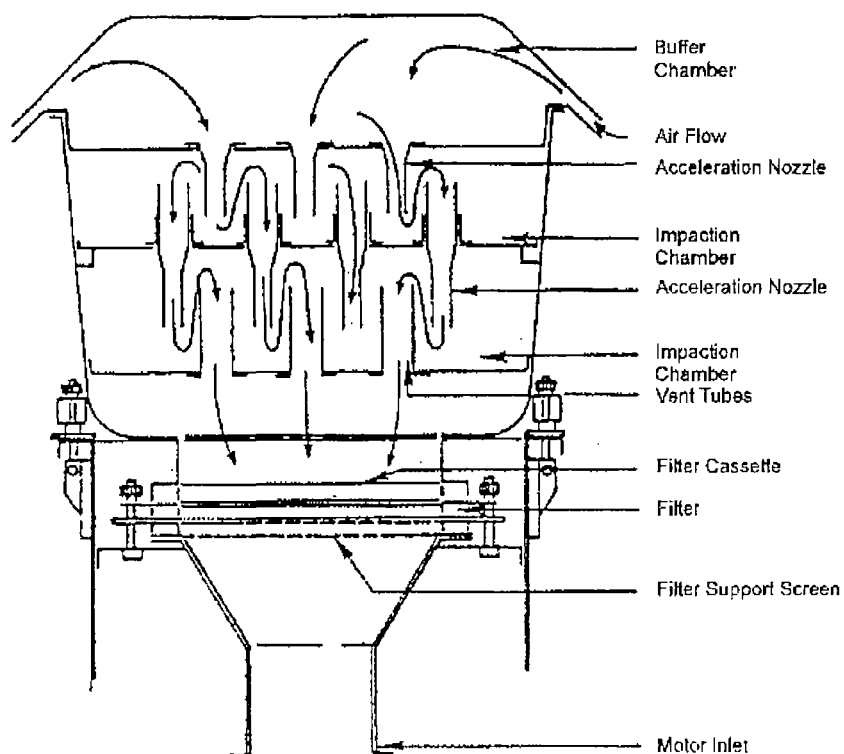


Figure 4. Schematic diagram of an impaction inlet for size select sampling for particulate matter.

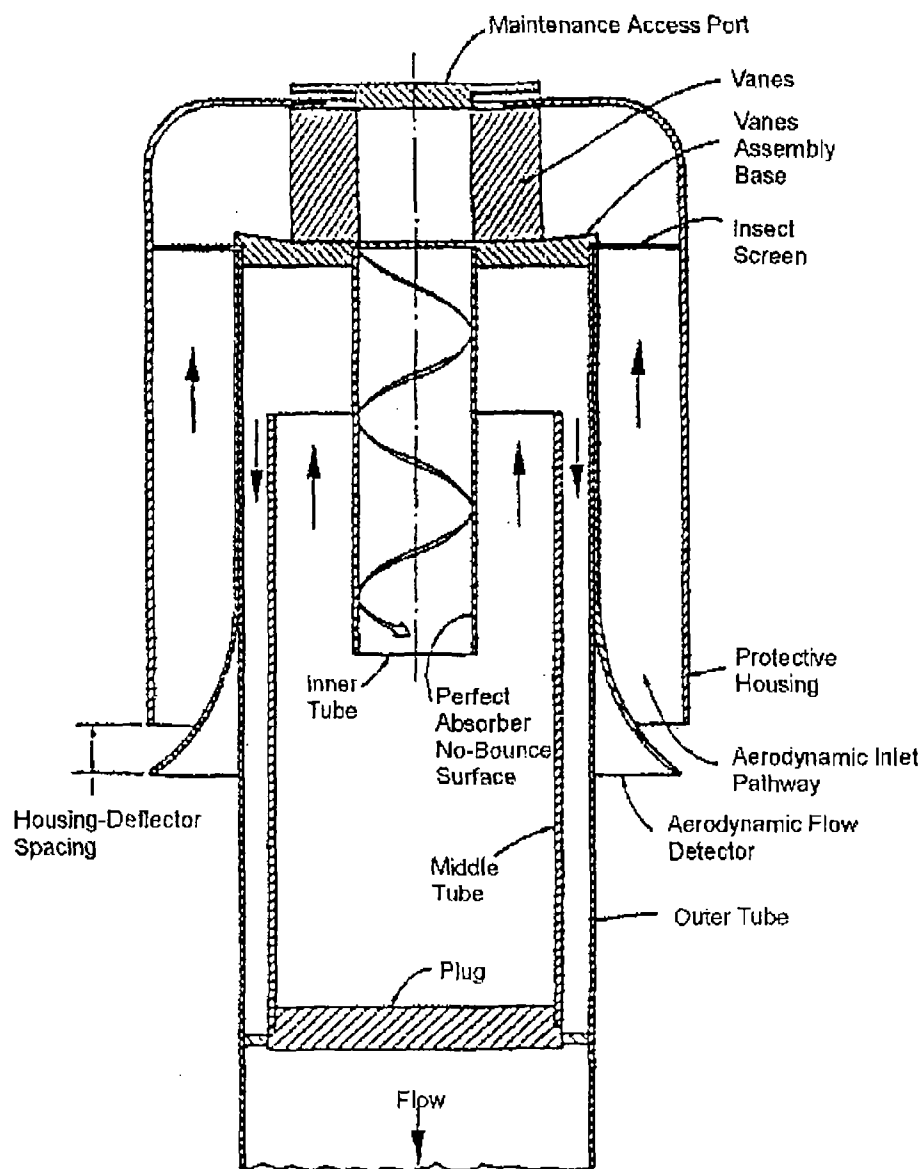


Figure 5. Schematic diagram of a cyclonic inlet for size select sampling for particulate matter.

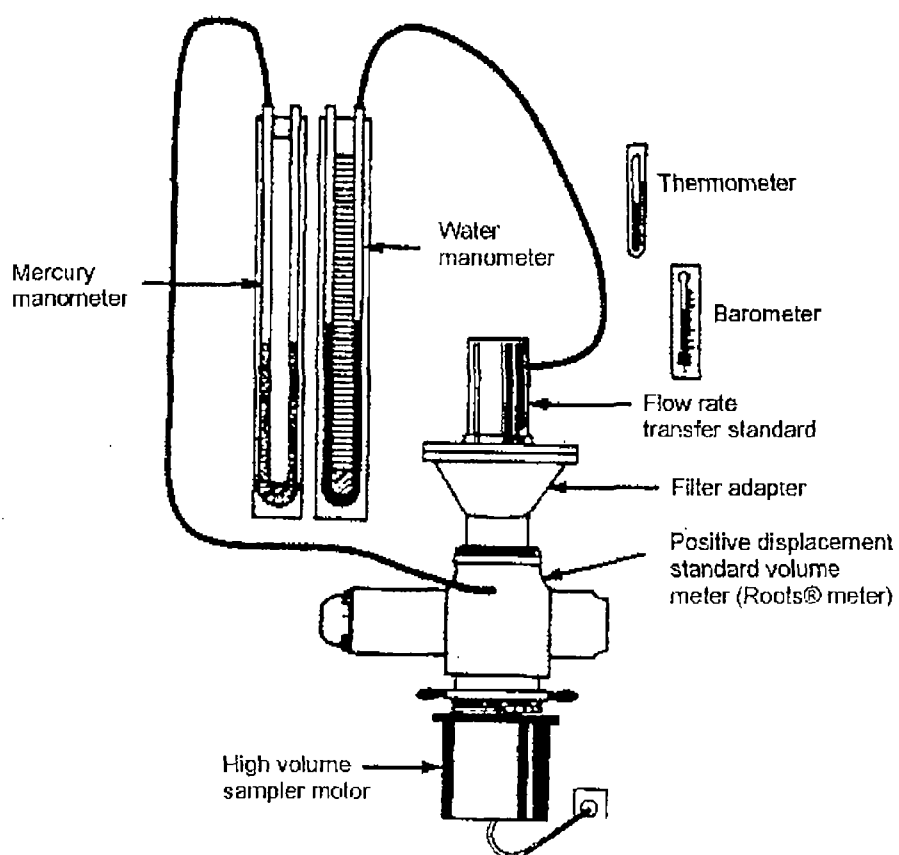


Figure 6. Flow rate transfer standard calibration setup.

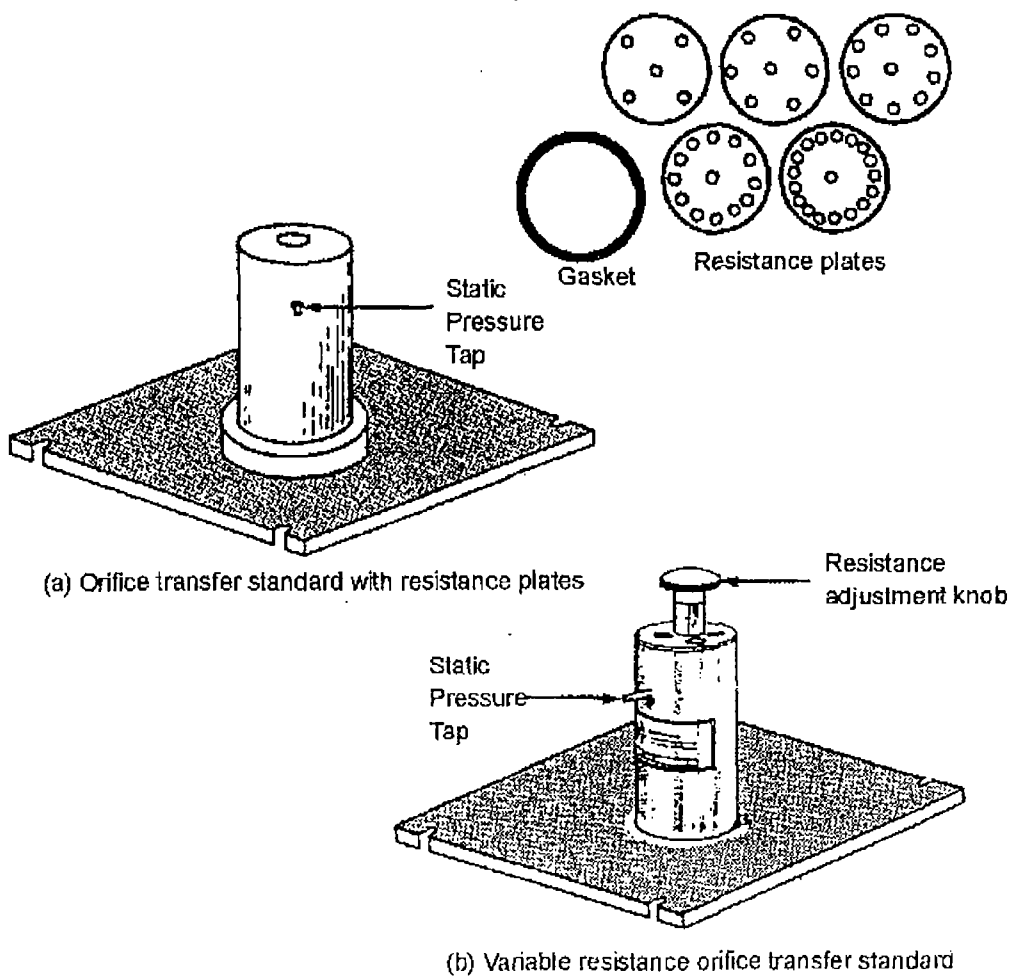


Figure 7. Typical orifice-type flow rate transfer standards.

*NOTE: For PM₁₀ monitoring, a calibration curve corrected to standard conditions is optional.

Figure 8. Example orifice transfer standard certification worksheet.

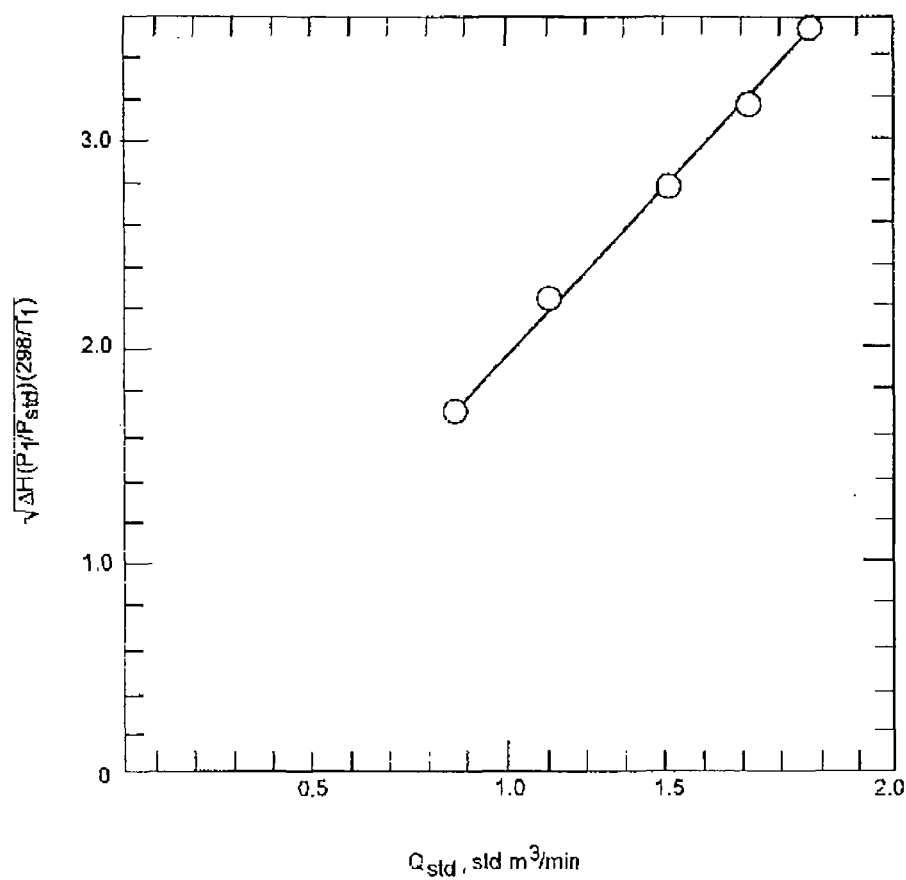


Figure 9. Typical calibration curve for a flow rate transfer standard.

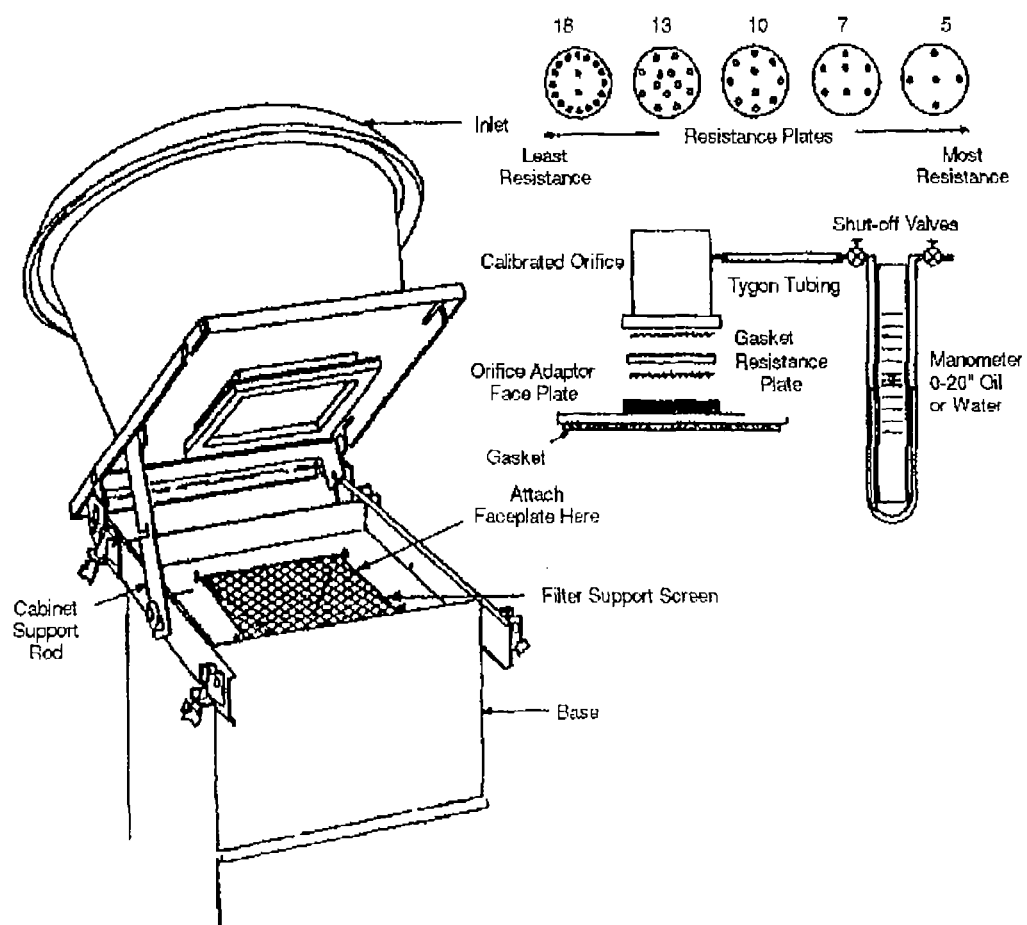


Figure 10. Typical calibration set-up for a mass flow controller (MFC).

Figure 11. Example MFC sampler calibration data sheet.

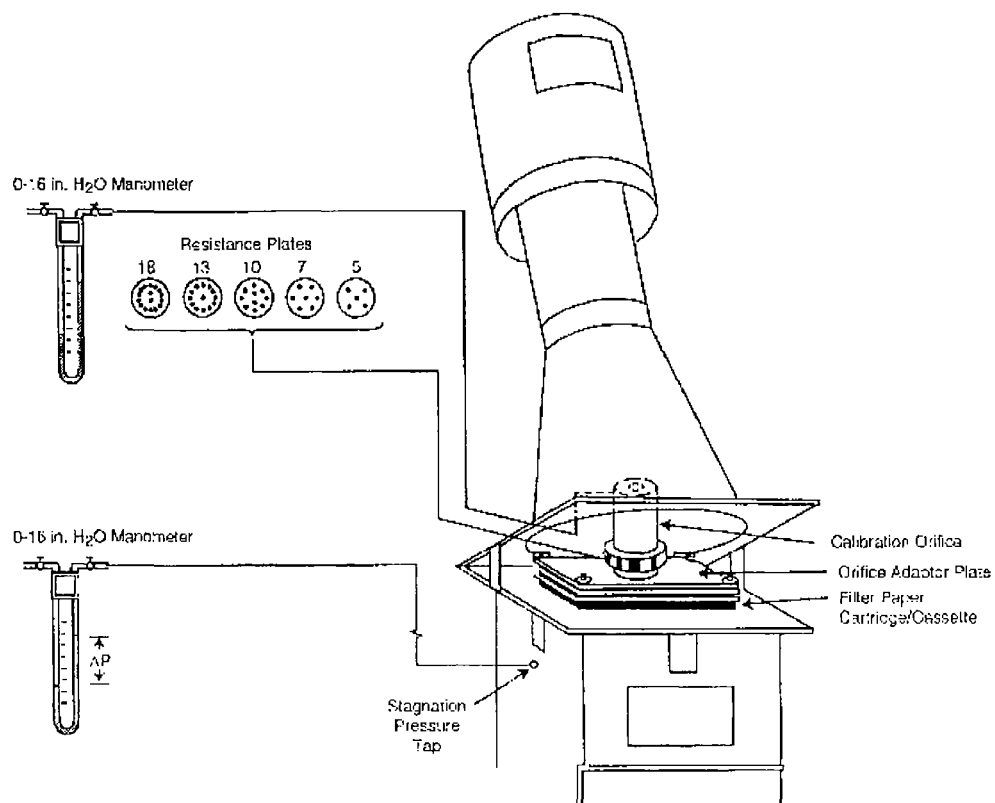


Figure 12. Calibration of a typical volumetric flow controller (VFC).

VFC SAMPLER CALIBRATION DATA SHEET						
Station Location _____		Date _____		Time _____		
Sampler Model _____		S/N _____		Operator _____		
Pa _____ mm Hg.		Ta _____ °C		K, Unusual Conditions _____		
Orifice S/N _____		Orifice Calibration Date _____				
Orifice Calibration Relationship: $m =$ _____ $b =$ _____ $r =$ _____						
Plate No.	ΔH ₂ O (in.)	ΔPsig (mm Hg) ^a	P1=Pa-ΔPsig (mm Hg)	P1/Pa (mm Hg)	Qa (orifice) flow rate ^b (m ³ /min)	Qa (orifice) [Ta] ^{1/2}
Operational Flow Rate						

^amm Hg = 25.4 (in. H₂O/13.6)

^bQa (orifice) = $1/m \{[(\Delta H_2O) (Ta/Pa)]^{1/2} - b\}$

^c% Difference = $\left[\frac{Qa \text{ (sampler)} - Qa \text{ (orifice)}}{Qa \text{ (orifice)}} \right] [100]$

Sampler Calibration Relationship

☐ Lookup Table Validated (i.e., % difference < 4)

☐ New calibration relationship:

$(X = \frac{Qa \text{ (orifice)}}{[Ta]^{1/2}}, Y = (P1/Pa)$

$m =$ _____ $b =$ _____ $r =$ _____

For subsequent calculation of sampler flow rate:

$Qa = \{[P1/Pa - b][Ta]^{1/2}\} (1/m)$

Operational Flow Rate _____ m³/min

Qa (Orifice)	Qa (sampler) (Lookup Table)	% Difference ^c

Figure 13. Example VFC sampler calibration data sheet.

MFC SAMPLER FIELD DATA SHEET			
Station Location _____		Date _____	SAROAD# _____
Sampler Model _____		S/N _____	
Filter ID No. _____	Pav _____ mm Hg.	Tav _____ °C	K _____
Sampler Manometer Readings		Flow Recorder Readings	
Initial ΔP_{ex} _____ in. H ₂ O		Mean I _____	
Final ΔP_{ex} _____ in. H ₂ O			
Mean ΔP_{ex} _____ in. H ₂ O			
Sampler Calibration Relationship: $m =$ _____ $b =$ _____ $r =$ _____			
\bar{Q}_a _____ m ³ /min		Elapsed Time _____ min	
$\bar{Q}_a = \{[\text{mean } \Delta P_{ex} (T_{av} + 30)/P_{av}]^{1/2} - b\} \{1/m\}$			
$\bar{Q}_a = \{\text{mean I} [(T_{av} + 30)/P_{av}]^{1/2} - b\} \{1/m\}$ for flow recorders			
Operator _____			
Comments: _____			
Laboratory Calculations:			
\bar{Q}_{std} _____ std m ³ /min		Gross weight (Wg) _____ g	
$\bar{Q}_{std} = \bar{Q}_a (P_{av}/P_{std}) (T_{std}/T_{av})$		Tare weight (Wt) _____ g	
V_{std} _____ std m ³		Net Weight (Wn) _____ g	
$V_{std} = (\bar{Q}_{std}) (\text{elapsed time})$		PM10 Concentration _____ $\mu\text{g}/\text{std m}^3$	
		PM10 Concentration = $(W_n) (10^6)/V_{std}$	

Figure 14. Example MFC sampler field data sheet.

VFC SAMPLER FIELD DATA SHEET			
Station _____		Date _____	
Location _____		SAROAD# _____	
Sampler Model _____		S/N _____	
Filter ID No. _____	Pav _____ mm Hg,	Tav _____ °C	K _____
Relative Stagnation Pressure Readings		Absolute Stagnation Pressure	
Initial ΔP_{stg} _____ mm Hg	$\bar{P}_1 =$ _____ mm Hg		
Final ΔP_{stg} _____ mm Hg	$\bar{P}_1 = P_{av} - \text{Average } \Delta P_{stg}$		
Average $\Delta P_{stg} =$ _____ mm Hg			
Average Stagnation Pressure Ratio (\bar{P}_1/P_{av}) _____			
Average Flowrate (\bar{Q}_a) * _____ m ³ /min		Elapsed Time _____ min	
*Obtained from manufacturer's lookup table (or from alternate calibration relationship)			
Operator _____			
Comments: _____			

Laboratory Calculations:			
\bar{Q}_{std} _____ Std m ³ /min	Gross Weight (Wg) _____ g		
$\bar{Q}_{std} = \bar{Q}_a (P_{av}/P_{std}) (T_{std}/T_{av})$	Tare Weight (Wt) _____ g		
V_{std} _____ std m ³	Net Weight (Wn) _____ g		
$V_{std} = (\bar{Q}_{std}) (\text{Elapsed Time})$	PM10 Concentration _____ $\mu\text{g}/\text{std m}^3$		
	PM10 Concentration = (Wn) (10 ⁶)/Vstd		

Figure 15. Example VFC sampler field data sheet.

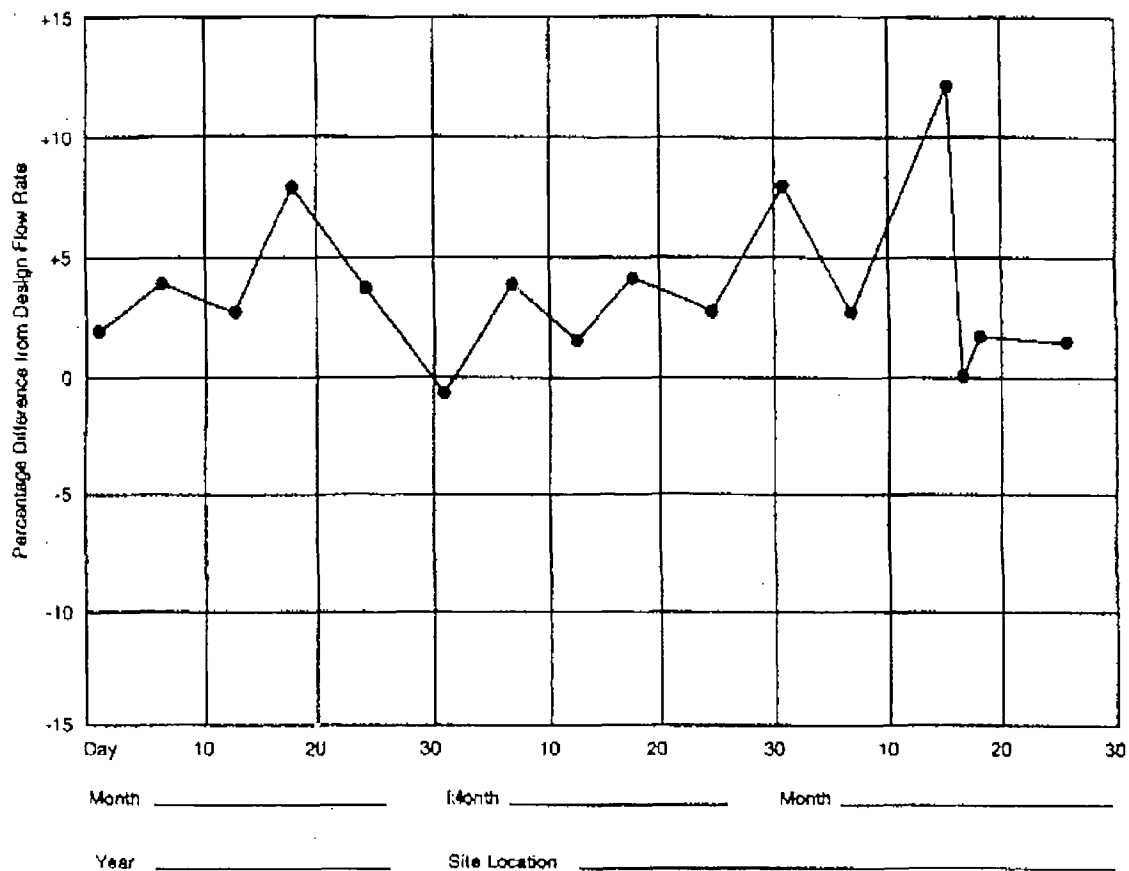


Figure 16. Field data control chart.

STANDARD OPERATING PROCEDURE NO. 600

SITE HABITAT CHARACTERIZATION

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SOP No. 600

TABLE OF CONTENTS

Section	Page
1. INTRODUCTION	1
1.1 Overview	1
1.2 Objective	1
1.3 Equipment and Supplies for Field Component	2
2. PROCEDURES	2
2.1 Desktop Study	2
2.2 Field Reconnaissance	3

STANDARD OPERATING PROCEDURE NO. 600 SITE HABITAT CHARACTERIZATION

1. INTRODUCTION

1.1 Overview

This Standard Operating Procedure (SOP) was prepared to provide instructions for habitat characterization. This SOP addresses both desktop studies and field reconnaissance.

This SOP will be implemented in accordance with the following governing documents:

- RI/FS Work Plan, which provides an overview of the site background and conceptual model and describes the overall investigative goals and scope of work for the RI/FS;
- Health and Safety Plan (HASP), which identifies all physical, chemical, and biological hazards relevant to each field task and provides hazard mitigators to address these hazards;
- Field Sampling Plan (FSP), which provides details for field sampling locations and procedures and which will be most frequently used by field staff on-site; and
- Quality Assurance Project Plan (QAPP), which is written to establish protocols necessary to ensure that the data generated are of a quality sufficient to ensure that valid conclusions are drawn from the site characterization.

1.2 Objective

As an early step in screening-level problem formulation, fundamental knowledge of the potential environmental setting and chemical contamination at a site must be documented. If a site is found to have some potential for ecological impacts, the habitats and species being affected may need to be characterized by personnel specialized in the ecological assessment. The goal of the habitat characterization is to identify and characterize the current and potential threats to the environment from a hazardous substance release. Threats to the environment include existing adverse ecological impacts and the risk of such impacts in the future.

Site ecological resources (species and habitats) present at the site are typically identified through a site visit and a review of any existing data and documented. Performed by qualified personnel experienced in biological and ecological assessment, the site investigator(s) will identify and describe natural areas (e.g., upland forest, on-site stream, nearby wildlife refuge) and disturbed/man-made areas (e.g., waste lagoons). The characterization will result in a description of habitats present on site that may be potentially contaminated or otherwise disturbed. This information will be used to assist the site manager in determining whether contamination has migrated from source areas and resulted in "off-site" impacts or the threat of impacts in addition to on-site threats or impacts.

1.3 Equipment and Supplies for Field Component

In preparation for the site survey, the study team will bring the following items to the site:

- Aerial photographs
- Site and vicinity topographic base map(s)
- Required personal protective equipment (PPE) per the HASP
- Camera with telephoto
- Collection containers for items, such as vegetation vouchers
- Logbook and indelible ink pens
- Plant and Animal Field Keys
- Binoculars

2. PROCEDURES

2.1 Desktop Study

The habitat characterization will begin with three desk-top tasks as follows:

- review of available site technical reports, natural resources study reports, maps from sources such as the U.S. Geological Survey, State Resource Agencies, and USFWS National Wetlands Inventory;

- review and habitat interpretation of available, recent aerial photographs;
- communication with appropriate State and Federal natural resource agencies (e.g., U.S. Fish and Wildlife Service, Illinois Natural Heritage Program; State Game or Fisheries Departments) in the form of letters of inquiry about current status of known occurrences of rare, threatened, or endangered species or sensitive habitats;

2.2 Field Reconnaissance

The second major component of habitat characterization entails a site visit conducted by an experienced biologist or ecologist to determine what plants, animals, and habitats exist or can be expected to exist in the on-site and bordering habitats.

Activities to be conducted during the habitat characterization site visit will include description or identification of the following:

- the layout and topography of the site;
- existing aquatic, terrestrial, and wetland ecological habitat types (e.g., forest, old field), and estimate the area covered by those habitats (including mapping areas that are unnaturally denuded);
- sources of contamination or potential contamination transport routes (e.g., areas of no or stressed vegetation, runoff gullies to surface waters) on and near the site;
- potentially sensitive environments;
- soil and water types, land uses, and the dominant vegetation species present; and
- direct or photographic observations and/or signs of animal species (animal tracks, trails, and burrows or other ecological features onsite and in the vicinity).

Field observations will be kept in bound logbooks with numbered pages per the FSP and QAPP. Entries will be initialed by the notetaker(s). The time, location, and subject of site photographs will be recorded in the field notebook.

